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THE USE OF DISTILLERS', BREWERS' DRIED GRAINS, AND MALT SPROUTS FOR HORSES[1]

E. W. CRAMPTON[2]

Macdonald College, McGill University, P.Q.

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Horse feeding is encumbered with numerous beliefs and prejudices which have in particular circumstances led to economically unsound feeding practices. One of the commonest of such beliefs in Eastern Canada holds that oats have special virtues; are irreplaceable by other feeds; and that rations which do not consist largely of oats are unsatisfactory, if indeed not unsafe, for horse feeding. The tenacity with which this trust in oats and distrust of other grains or grain by-products is held among practical horsemen is perhaps not surprising, when similar views appear to be held by those who have access to scientific literature, which without exception fails to support the oats superiority belief.

The Division of Animal Husbandry of the U.S. Bureau of Animal Industry says in *Food and Life*[3] "Many horsemen consider that oats have no equal as a horse feed. This may be erroneous, however, as both experimental and practical feeding experience have shown that some other feeds, when properly combined may be either equal or superior to oats. . . . Most experiments have shown very little difference between the feeding values of corn and oats for work stock. . . . Barley is used as the principal grain for horses in many parts of the West. . . . Wheat, rye, rice, and some leguminous seeds are used as feed for horses under limited conditions." This excerpt is typical of the statements in recognized tests on horse feeding, and in no case is it the opinion of nutritionists that horse rations need contain any oats at all, or, any other specific feedstuff. Indeed it appears that the beliefs regarding the indispensability of oats in horse feeding are held chiefly in districts in which oats is the common farm grain raised.

While there is an abundance of evidence to the effect that horses may be fed a variety of different grains, the only by-product of grain about which there appears to be any extensive knowledge is wheat bran.

There are, however, three other grain by-products on the Canadian feed market, all of which are likely to be cheaper per ton than the coarse grains. The spread is especially marked with oats, for this grain in commercial feed channels in Eastern Canada is usually somewhat out of line in price with respect to its feeding value. These three by-products are brewers' dried grains, malt sprouts, and distillers' dried grains. The latter is a wheat by-product and the other two come from barley.

In terms of their "botanical" description, malt sprouts are actually the sprouts of barley which has been allowed to start germination. These sprouts or rootlets are removed when still very short. They are dried and

[1] Contribution from the Faculty of Agriculture, McGill University, Macdonald College, Que., Canada Journal Series No. 203.
[2] Professor of Animal Nutrition.
[3] U.S.D.A. Yearbook 1939, pp. 763-786.

sold as a feedstuff. Brewers' and distillers' dried grains are almost analogous products from barley and wheat, respectively, at least in the sense that the chief portion of the original grain removed in the process leading to their production is starch. Roughly we have then in these two feeds, barley or wheat minus most of their original starch filling.

Chemically and nutritionally there are other differences between the entire grain and these two by-products. Several other nutrients which are water soluble may have been removed and not returned to the dried grains. And the loss of easily soluble nutrients will also mean that the nutrients remaining may be correspondingly of lower digestibility for species other than herbivora. For horses this latter is probably of minor significance. It seems certain that in the case of herbivora the cellulose and hemicellulose fractions of these feeds can be as well utilized as in roughage. And it is further known that herbivora appear to digest these complex carbohydrates about as completely as they do protein or ether extract.

All three of these by-products, however, are classed as high protein feeds. They contain about twice the protein found in the original grains due entirely to the fact that a non-protein material has been removed. The comparison of these by-products with their original grains and with oats is partly indicated in Table 1.

Table 1.—Partial chemical composition of barley and wheat and their by-products as compared to oats

Fraction	Barley	Brewers' dried grains	Malt sprouts	Wheat	Distillers' dried grains	Oats
Protein	12.8	20.7	28.1	12.0	24.0	12.5
Ether extract	2.3	7.2	1.8	2.0	6.1	4.4
Crude fibre	5.5	17.6	13.3	2.0	13.1	11.2
Non-fibre carbohydrate	67.0	42.5	43.4	71.6	45.0	60.7
Calcium	.07	.16	.26	.05	—	.10
Phosphorous	.32	.47	.68	.38	—	—

The fact that these by-products carry 20% or more of crude protein is very likely one reason they have usually been considered only as supplementary feeds—products to be used to increase the protein content of mixtures of cereal grains (as in cattle rations). Such products as the oil-meals have normally been appreciably more costly in Canada than low protein basal feeds. This has naturally led to the usual recommendations to use high protein feeds in minimum amounts consistent with adequate protein levels in the final ration. Thus brewers' grains, distillers' grains and malt sprouts, falling into the classification of protein supplements, have not been looked on as products to be used primarily for energy.

There is no evidence, however, that feeding more protein than bare minimum is harmful. Indeed surveys show that training table diets for football players often contain 25% protein, and all herbivorous animals while at pasture consume diets running up to 30% protein when calculated to an air-dry basis. When animals consume a surplus of protein, the extra is used for energy in the same way that carbohydrate is, and yields approximately the same number of calories of metabolizable energy per gram as does carbohydrate.

With these facts in mind, viz., that both fibre and non-fibre carbohydrates are well digested by herbivorous animals, and that surplus protein is an acceptable source of energy, the comparison of the total of the digestible nutrients between the feeds of Table 1 is interesting.

Feed	Total digestible nutrients
Barley	77%
Brewers' grains	68
Malt sprouts	71
Wheat	76
Distillers' grains (wheat)	80*
Oats	72

* Estimate.

These figures might lead to the conclusion that any one of these feeds would be as good as oats as a source of energy, and there can be no doubt as to the adequacy of protein when oats is considered to contain enough of this material for work-horse feeding.

Experimental evidence, on the other hand, appears to be entirely lacking on the feeding value of malt sprouts and of wheat distillers' grains for horses, while only two experiments were found in which brewers' dried grains were compared to oats. These were summarized by the conclusion that "when cheap in price they may be used economically for half the oats in feeding work-horses—equalling oats pound for pound in feeding value." In a third trial brewers' dried grains were reported to be constipating to horses.

Somewhat aside from the matter of the supply of nutrients, there is the problem of the physical nature of feeds intended for horse feeding. It is well known that injudicious feeding practices may result in digestive disturbances such as "colic." It is the danger of colic that leads many horsemen to avoid heavy grains such as corn or wheat. Indeed, oats, because of its hull, is considered as a safer feed than the heavier grains. The bulkiness of oats is reflected in its fibre content of 11%. Reference to Table 1 indicates that taking oats as a standard, all three of the by-products, malt sprouts, brewers' grain, and distillers' grain, carry sufficient fibre to insure freedom from digestive troubles traceable to heavy, compact feeds.

Prompted in part by the absolute scarcity and relative high prices of oats at the time, and in part by the belief that a horse is no more demanding in its feed needs than a dairy cow, a series of observational tests was started in the fall of 1943 in which it was planned to feed farm horses, which had for years been accustomed to oats, on rations composed of their usual hay allowance plus either wheat distillers' dried grains, or brewers' dried grains or dried malt sprouts.[4] The horses were to be managed in accordance with the needs for work to be done.

They were to be weighed about twice a month and the allowances of the oat substitutes adjusted to keep the animals at constant live weights.

[4] These feeds were very kindly supplied by Distillers' Corporation Limited, National Breweries Limited, and Canada Malting Company, respectively.

From November 13, 1943 to the following April 23, 1944, six horses were available for the test. A second trial was carried out between June 1, 1944 and November 1, 1944, involving 13 animals, and is described later.

Table 2 summarizes the pertinent facts about these horses as at the time they were put on their respective trials.

TABLE 2.—DESCRIPTION OF HORSES USED IN OAT-SUBSTITUTE FEEDING TESTS

Stable	Name	Av. daily		Initial weight	Description
		Hay	Oats		
		lbs.	lbs.	lbs.	
1	Rivolette	12	13.5	1750	Percheron mare—fat—good feeder.
	Jack	12	12.0	1600	Clyde gelding—high strung, nervous temperament—fussy feeder—never fat.
	George	—	13.5	1600	Clyde gelding—good feeder.
	Colt	—	13.0	1565	Clyde gelding—quiet disposition—good feeder.
	Chief	6	8.0	1120	Thoroughbred gelding—quiet—not a heavy feeder.
	Nimble	6	6.0	1070	Standard-bred mare—nervous—good feeder.
2	Cockatoo	8	5.0	1080	Morgan mare—quiet—good feeder—easy keeper.
	Chips	8	5.5	1050	Morgan-type gelding — quiet — good feeder (in particularly poor flesh at the start).
3	Doll	—	8.2	1500	French Canadian mare — fat—good feeder.
	Charlie	—	7.7	1450	French Canadian gelding — fat — fair feeder.
4	Pearl	—	13.7	1500	Percheron mare—fat—fussy feeder.
	Pete	—	14.5	1375	French Canadian gelding—fat—indifferent feeder.
	Grayson	—	13.5	1375	Percheron-type gelding — fat — poor feeder.
	Jess	—	13.7	1260	French-Canadian mare — fat — good feeder.

TRIAL I

In Stable No. 1 were four horses used in Trial I. They were individually quite different. Rivolette was an exceptionally easy keeper, and in addition was a greedy feeder, while Jack was a tall, raw-boned horse that was temperamental about his feed and his surrounding. He always questioned changes in feed and frequently had to be coaxed to eat his full allowances. Chief and Nimble differed particularly as to hay consumption. Chief would eat only the fine parts of his hay while Nimble ate not only her hay but also much of her bedding. Ske kept fat while the gelding stayed in good condition but never seemed to put on much extra weight.

Cockatoo and Chips, used in both tests, were both very quiet, chunky types and maintained their weights on a minimum of feed.

For the first period of the trial these six horses were transferred over a period of two weeks from the ration of oats previously fed to equal allowances by weight of a mixture of 99% dried brewers' grains and 1% fine salt.

Jack questioned the new feed for two or three days and during the first two weeks on the straight brewers' grains both Rivolette and Jack were rather fussy feeders. Their daily allowances were not eaten promptly but were cleaned up before the next morning.

Live weights recorded after the first two weeks on the brewers' grains showed that Rivolette had gained 100 pounds, Cockatoo had lost some 70 pounds. Their actual measured feed consumption was found to be less in most cases than had been arranged for due doubtless to the feeder's unfamiliarity with the bulkiness of the product. (To obtain feed records each horse was provided with a separate feed bin into which weighed amounts of feed were put as needed. Actual feeding was done by measure. At the end of a given period (usually two weeks) the feed remaining in the bin was weighed and the horse charged with the quantity of feed which had been removed).

Following the first weighing Rivolette's feed was reduced by some two pounds per day, while that for Cockatoo and Chips was increased about half a pound daily. With these adjustments, allowances were satisfactorily eaten throughout the test.

The feeding of dried brewers' grains was continued for 42 days (until January 2, 1945). The summary of the live weights and feed records are shown in Table 3.

TABLE 3.—LIVE WEIGHTS AND FEED CONSUMPTION RECORDS OF HORSES ON BREWERS' GRAINS

Horse	Live weights		Gain 42 days	Average daily feed	
	Nov. 21	Jan. 2		Brewers' grains	Hay*
			lbs.	lbs.	lbs.
Rivolette	1750	1760	10	11	12
Jack	1600	1590	−10	10	12
Chief	1120	1140	20	6.5	6
Nimble	1070	1060	−10	5.5	6
Cockatoo	1080	1060	−20	5.5	8
Chips	1050	1080	30	5.5	8

* Estimated from periodic weighings.

During this period none of these horses were worked. Feces were entirely normal throughout the period and no evidence of leg swelling was found. Hair coats were in excellent condition.

Apparently daily allowances of 5 to 6 pounds of brewers' dried grains and 6 to 7.5 pounds of timothy hay per 1000 pounds body weight were adequate for winter maintenance feed.

Malt Sprouts

At the end of the first feeding test, all six horses were transferred from brewers' grains to malt sprouts. This feed has a rather pronounced taste and aroma and even though at the start a mixture consisting of 25% brewers' grains, 25% oats, and 50% malt sprouts was used, the four horses

of Stable No. 1 refused the feed for about two days. When the day's feed for each horse was moistened with about a quart of water containing one-third pint of molasses it was readily eaten.

After a week's time, straight malt sprouts (containing 1% salt) replaced the mixture of grains. It was necessary, however, to continue for another week the use of small amounts of molasses in Stable No. 1 to ensure the consumption of the full allowance. Cockatoo and Chips (Stable No. 2) never objected to the malt sprouts and ate well throughout the 6 weeks period.

On January 6, Rivolette, following a chilling in a trip to the blacksmith, developed colic. An aloes ball was given her. Manure passed was normal and there was no evidence of impaction. Regular feed was withheld until January 10. Jack consistently refused to eat his full feed allowance though working regularly during this period. Other horses were idle. On February 13 the malt sprout feeding was discontinued. The record of live weights and feed consumption during the period are shown in Table 4.

TABLE 4.—LIVE WEIGHTS AND FEED CONSUMPTION RECORDS OF HORSES ON MALT SPROUTS

Horse	Live weights		Gain 42 days	Average daily feed	
	Jan. 2	Feb. 13		Malt sprouts	Hay
			lbs.	lbs.	lbs.
Rivolette	1760	1880	120	10.6†	12
Jack	1590	1520	−70	12.2	12
Chief	1140	1110	−30	6.4	8
Nimble	1060	1070	10	6.4	8
Cockatoo	1060	—*	—	6.0	8
Chips	1080	—*	—	6.0	8

* Not weighed due to ice and snow conditions.
† For 35 days only, and including molasses when used.

Regardless of the gains or losses in liveweight which occurred while on this feed, it was evident that *the acceptableness of malt sprouts must be regarded as uncertain* and unpredictable, depending on the individual likes and dislikes of the horses.

Distillers' Dried Grains (Wheat)

On February 13, the horses in Stables No. 1 and No. 2 were started on distillers' dried grains. The change from malt sprouts was made abruptly. In view of the gains made by Rivolette during the previous period, and her already over-fat condition, she was started out on an allowance of 9 pounds daily—a reduction of about 2 pounds per day from the previous period.

All horses accepted the wheat distillers' grains without question. Rivolette, however, was put to work and as a result lost about 90 pounds in the first two weeks. Her ration accordingly was raised to 12 pounds per day.

On about March 1, a change was made in the hay fed in Stable No. 1. A coarser, poorer quality product replaced the good quality timothy fed up to that date. This was at once reflected in a lower consumption and in obvious wastage, and in a drop in the weights of all horses. On restoration of good quality hay plus a temporary increase in the allowances of the grains, most of the lost weight was regained. In Stable No. 2 the quality of the hay was especially poor all through this period.

The six horses were carried for 70 days on the distillers' dried grains. No undesirable conditions were noted with respect to condition of legs or of manure. The feed appeared to be acceptable as the entire grain portion of the ration. The records for the 70-day period are given in Table 5.

TABLE 5.—LIVE WEIGHTS AND FEED CONSUMPTION RECORDS OF HORSES ON WHEAT DISTILLERS' GRAINS

Horse	Live weight		Gain 70 days	Average daily feed	
	Feb. 13	Apr. 23		Distillers' grains	Hay
			lbs.	lbs.	lbs.
Rivolette	1880	1860	−20	11.7	12
Jack	1520	1540	20	13.1	12
Chief	1110	1070	−40	8.0	6
Nimble	1070	1050	−20	7.4	8
Cockatoo	1060*	1060	—	6.1	7
Chips	1080*	1080	—	6.1	7

* Weight, January 2, 1944.

In considering the actual changes in body weights of these horses, it should be noted that the period covered is 70 days while those for the malt sprouts and brewers' grains were but 42 days each. If these changes are real, i.e., to be charged to feed and not to the variations in single weights resulting from defecation or watering, etc., then they should be reduced by 40% to be comparable to those of the 42-day tests. Observation of the horses did not lead to the conclusion that they were changing weight appreciably over the period as a whole.

Concerning the distillers' grains; it proved to be *an acceptable oat substitute for winter feeding of horses who were worked only occasionally* but were for the most part idle.

General Results of the Winter Feeding Tests

Taking the 154-day feeding period as a whole, there was no evidence, save for the lack of palatability of the malt sprouts, that the nutritive value of these feeds differed from oats or from each other when they formed the entire non-roughage feed of the horse. No cases of swollen legs were found nor any evidence of digestive disturbances. Those individuals that did not object to the malt sprouts did well on it.

The weight changes over the whole period are interesting.

Table 6.—Weights of horses at start and end of winter feeding

Horse	Nov 21	Apr. 23	Weight change
Rivolette	1750	1860	+110
Jack	1600	1540	− 60
Chief	1120	1070	− 50
Nimble	1070	1050	− 20
Cockatoo	1080	1060	− 20
Chips	1050	1080	+ 30
	Average per horse		1.7 lbs.

In connection with these figures it may be noted that Jack and Chief undoubtedly really lost weight during the winter. Chief had just come to the stable at the opening of the test. He had been on pasture during the summer and then on an allowance of 8 to 10 pounds of oats plus unlimited hay in his former stable. He had shown a little difficulty in eating and his previous owner had been unsuccessful in having dental work done on him. It was partly for this reason that he became available for these tests. The use of ground feed proved advantageous and he maintained his weight until the coarser hay was introduced, of which he refused considerable portions.

Jack on the other hand proved to be temperamental in his feeding as well as in his behaviour. He had never been an easy keeper on any feed. For him the wheat distillers' grains were more satisfactory than either of the other feeds.

For winter feeding of nearly-idle horses, the kind of hay available is undoubtedly an important factor in determining the amounts of grain feed needed to maintain a given condition of live weight.

TRIAL II

Summer Feeding

The first series of tests gave no information relative to the value of any of these products for horses at work—where the energy of the ration would be a greater factor and therefore where palatability might determine the limits to which the feeds could be used.

For the second series of trials some changes were made in the horses used. Jack was omitted largely because he was giving his driver some difficulty, and was generally unsuited to feed testing work. Two others from the same stable, George, a mature clyde gelding and an unnamed three-year old clyde colt, were chosen along with Rivolette and the two light horses, Chief and Nimble. Chips and Cockatoo from Stable No. 2 were not available until July 1. Six additional horses from Stables Nos. 3 and 4 were also used. The general plan of feeding was the same as in the previous periods except that no record was made of hay consumption. This was partly due to the fact that some of the teams had access to pasture, nights and weekends.

Malt sprouts was omitted as the results during series 1 indicated that one of its limiting factors was palatability. It was also decided to divide

the horses into two groups—one to be fed continuously on brewers' grains and the other on wheat distillers' grains. Salt was to be fed individually to each horse.

All horses were started during the first week in May on a mixture of equal parts of crushed oats and brewers' dried grains. On June 1 the horses in Stables No. 1 and No. 2 were changed to straight wheat distillers' grains; those in Stables No. 3 and No. 4 to brewers' dried grains.

The main feeding period continued through August, though the two horses in Stable No. 2 and the pair in Stable No. 3 were left on their respective rations through October. Weighing was done approximately at fortnightly intervals but this was not strictly adhered to because of summer work schedules. For purposes of this report all weighings in a given calendar month were averaged and taken as the average weight of the horse during that month. No unusual fluctuations were found in adjacent weighings and the average figures appear to give a true picture of the success in adjusting feed allowances to maintain the horses in constant live weight.

In Table 7 are summarized the average monthly weight of the horses and their average daily intakes of brewers' grains or distillers' grains.

TABLE 7.—WEIGHTS OF HORSES AND FEED CONSUMPTION RECORDS—TRIAL II

Feed	Horse	June		July		August	
		Weight	Feed	Weight	Feed	Weight	Feed
Wheat distillers' grains	Rivolette	1850	11.0	1840	15.0	1840	11.5
	George	1600	13.5	1550	15.2	1570	11.0
	Colt	1565	13.3	1560	15.4	1530	10.7
	Chief	1110	8.3	1100	10.4	1090	8.9
	Nimble	1075	8.3	1100	11.3	1100	6.7
	Chips	—	—	1040	5.0	1020	5.0
	Cockatoo	—	—	1015	5.0	1000	5.0
Brewers' dried grains	Doll	1500	8.2	1540	7.4	1500	8.1
	Charlie	1450	7.7	1450	7.9	1465	7.5
	Pearl	1500	13.7	1530	11.0	1550	10.7
	Pete	1375	14.5	1390	12.0	1400	11.7
	Jess	1260	13.7	1300	12.0	1315	10.7
	Grayson	1375	13.5	1375	12.0	1375	10.7

Because of varying work schedules it is impossible to compare directly the quantities of feed needed per unit of live weight of animal in these tests. From the data of Table 7 and the observations made during the test some results may warrant specific note.

(1) There was no evidence that more than one pound of grain need be fed per 100 pounds of live weight of horse even when the animals are at farm work.

(2) Horses differ considerably in their feed requirements per unit of their weight depending on their individuality more than on their weight. This is doubtless influenced also by their hay consumption. Horses willingly eating liberal amounts of good quality hay need much less grain than those whose hay intake for one reason or another is low.

(3) There was no difficulty in getting any of the horses to eat enough of the brewers' or distillers' grains to maintain their live weights, hay being fed in amounts readily cleaned up. Night pasturing appeared to save hay, but not grain. It may also be noted that while horses were not at work, they would frequently refuse to eat the full "work allowance" of the brewers' grains. Thus it might be found that these feeds could not easily be used for fattening horses as for show or for sale unless mixed with more palatable feeds.

(4) No adverse effect of either of these feeds was found at any time during the trials. Hair coats remained in good condition; no digestive disturbances occurred; and no leg trouble was experienced.

Though not a part of these tests, it may be of interest that six of these horses have continued for all or a part of the past winter on one or other of these feeds as the only grain used. Results have been entirely satisfactory.

CONCLUSIONS

To the extent that they can be drawn for observational tests of this kind, the following conclusions relative to the usefulness for horse feeding of brewers' dried grains, distillers' dried grains (from wheat), and malt sprouts appear to be warranted.

Malt Sprouts, probably because of a characteristic and pronounced aroma may be refused by some horses if used as the entire ration other than hay. If diluted with an equal weight of some other feed, as ground oats, it will probably be readily eaten. For those horses who do not object to it, this feed has proved satisfactory.

Brewers' Dried Grains, have been found approximately equal to oats as a work horse feed, on the basis that when used as the entire grain portion of the ration no larger allowances were needed to keep horses in constant body weight than had been needed of oats. In general this feed, if not offered in amounts in excess of those needed to maintain body weight, will be satisfactorily eaten by work horses. Some horses, however, may not readily clean up greater allowances than this, which might limit the usefulness of brewers' grains in fattening or fitting rations. When mixed with oats, this limitation was not apparent.

Distillers' Dried Grains (from wheat). This by-product appeared to be equal to oats under the conditions of this test. It may be noted that for one very hot week during July, the three draft horses in Stable No. 1 were on especially heavy work. As a consequence they lost considerable weight (about 50 pounds). Rather than increase the feed allowance, 20% barley was added to the distillers' grains to increase its weight per quart. Within two weeks the lost weight had been recovered, and during the next month the feed allowances were reduced as seen in Table 7. Distillers' grains were readily eaten as the sole grain allowance. The maximum offered was 1 pound per 100 pounds of live weight of the animal.

It seems logical to believe then that either brewers' dried grains or wheat distillers' grains may be used as all or any part of the grain allowance for farm horses.

A REVISION OF THE NORTH AMERICAN SPECIES OF THE PHASIA COMPLEX (DIPTERA, TACHINIDAE)[1]

By A. R. Brooks[2]

Science Service, Ottawa, Ont.

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SUMMARY

This paper is a revision of the North American species belonging to the *Phasia* complex as they occur north of Mexico. Twenty-three species and one subspecies belonging to ten genera are described and illustrated. Of these, one genus and eight species are recognized as new. A number of exotic genera are included in the keys for the purpose of comparison with our native forms.

Coquillett (1) placed the species belonging to the *Phasia* complex in two genera, *Phorantha* Rondani and *Alophora* R-Desvoidy, including some fifteen species, most of which he described at that time. Feeling that this revision was inaccurate as regards its commonest species, Robertson (7) attempted to revise the concept of *Phorantha occidentis* (Wlk.) of Coquillett which in the revision was placed with seven synonyms; the opinion was expressed that the true *occidentis* was not identifiable and that *occidentis* of Coquillett contained at least three distinct species, two of which Robertson then described. More recently, Townsend (8) recognized nine distinct genera as applying to the North American members of the group, classifying the complex as part of the subtribe Phasiina. Townsend's classification on the whole has not been accepted by the North American workers, Curran (2) placing the species in two genera, *Hyalomya* R-Desvoidy and *Alophora* R-Desvoidy, these two corresponding closely to Coquillett's *Phorantha* and *Alophora*.

HOST RELATIONS

The members of the *Phasia* complex possess in the females a long, sharp, piercing ovipositor with which thin shelled, unincubated eggs are injected directly into the body of the host. Known hosts are adult Hemiptera. Although adults of most species are rather common and easily captured around flowers, very little is known about their life histories or immature stages. Milliken and Wadley (5) working with *Hyalomyiopsis aldrichi* Townsend (reported as *Phasia occidentis* Wlk.) a parasite of *Nysius ericae* Schill. in Kansas, gives a summary account of its life history: the life cycle requires about 25 days and in this respect bears a close relationship to the habits of the host; the parasitism is almost entirely confined to the females of *Nysius*, the destruction of the males being negligible; it was also

[1] Contribution No. 2362, Division of Entomology, Science Service, Department of Agriculture, Ottawa.
[2] Junior Entomologist.

found that although the host is not always destroyed the egg laying capacity is much reduced. Painter (6) reported that the parasitism of *Lygus pratensis* Say by *Alophorella aeneoventris robertsonii* Townsend (reported as *Alophora opaca* Coq.) to be 2 to 4% in the overwintering generation, the parasite laying its eggs in the fall and overwintering as a partially grown maggot in the host, pupating in the soil the following spring.

CLASSIFICATION AND CHARACTERS OF IMPORTANCE

The tribe Phasiini in the general conception (Townsend, 8) contains two well marked reproductive-habit groups, those genera as *Pallasia* R-D. (*Cistogaster* Lat.), *Xysta* Meig., *Ectophasia* Townsend and allies which lay flattened unincubated eggs externally on the host and the members of the *Phasia* complex which inject eggs into the host. These habits are closely correlated with the stuctures of the male and female reproductive organs, and while other body characters of the two groups appear to intergrade and overlap, the genitalic characters will separate the two.

The *Phasia* complex may be characterized as follows:

> Body short and broad; abdomen oval and flattened, particularly in the male; chaetotaxy very poorly developed, the abdomen without macrochaetae or these very poorly developed; wings broad or narrow, generally with some darker markings but often clear; apical cell closed and with a long straight petiole; female genitalia in the form of a sharp piercer; male genitalia box-like, the large rectangular forceps covering most of the other structures.

Coquillett's division of the complex into two genera (1) was based on the bristling of the head, those species with the sides of the front hairy outside the frontal bristles being placed in the genus *Alophora* R-Desvoidy, while those without additional rows of hair on the front were placed in *Phorantha*. This arrangement will successfully place our species in two groups, but other characters show that the grouping is largely artificial. Curran's division of the complex into two genera (2), based on the pleural hair, those with dense yellow hair being placed in *Alophora* R-Desvoidy, those with black pleural hair in *Hyalomya* R-Desvoidy, is even less illuminating as some species have both yellow and black hair on the pleura, and there is every gradation between the two extremes.

It becomes evident after an examination of the genera involved that these fall into a number of natural divisions, each division with its own range of variables and taxonomic characters, the characters employed in one division being only partly usable in the next. There is furthermore a great difference in the ease of separation of the genera in the different divisions. In other words we have stable or mature divisions and unstable or young divisions. What is not generally realized, however, is that this very difference in stability provides one of the best characters for separating the divisions. It is proposed in this paper to divide the North American representatives of the *Phasia* complex into five major divisions; division I,

Heyneophasia TT. and allies; division II, *Phasia* Latr. and allies; division III, *Paraphorantha* TT. and allies; division IV, *Alophorella* TT. and allies; division V, *Hyalomya* R-D. and allies.

Of highest importance to our classification within the complex appears to be the structure of the head plus that of the wing venation. These characters outline in a general way the five main divisions. Characters of second importance appear to be the arrangement of bristles particularly on the head, plus the structure of the female abdomen in the *Phasia* and *Hyalomya* divisions where these characters are distinctive or the structure of the male wing in the *Alophorella* and *Hyalomya* divisions where the females are much alike. Of third importance (chiefly generic) are minor characters of the above plus colour and pollinosity.

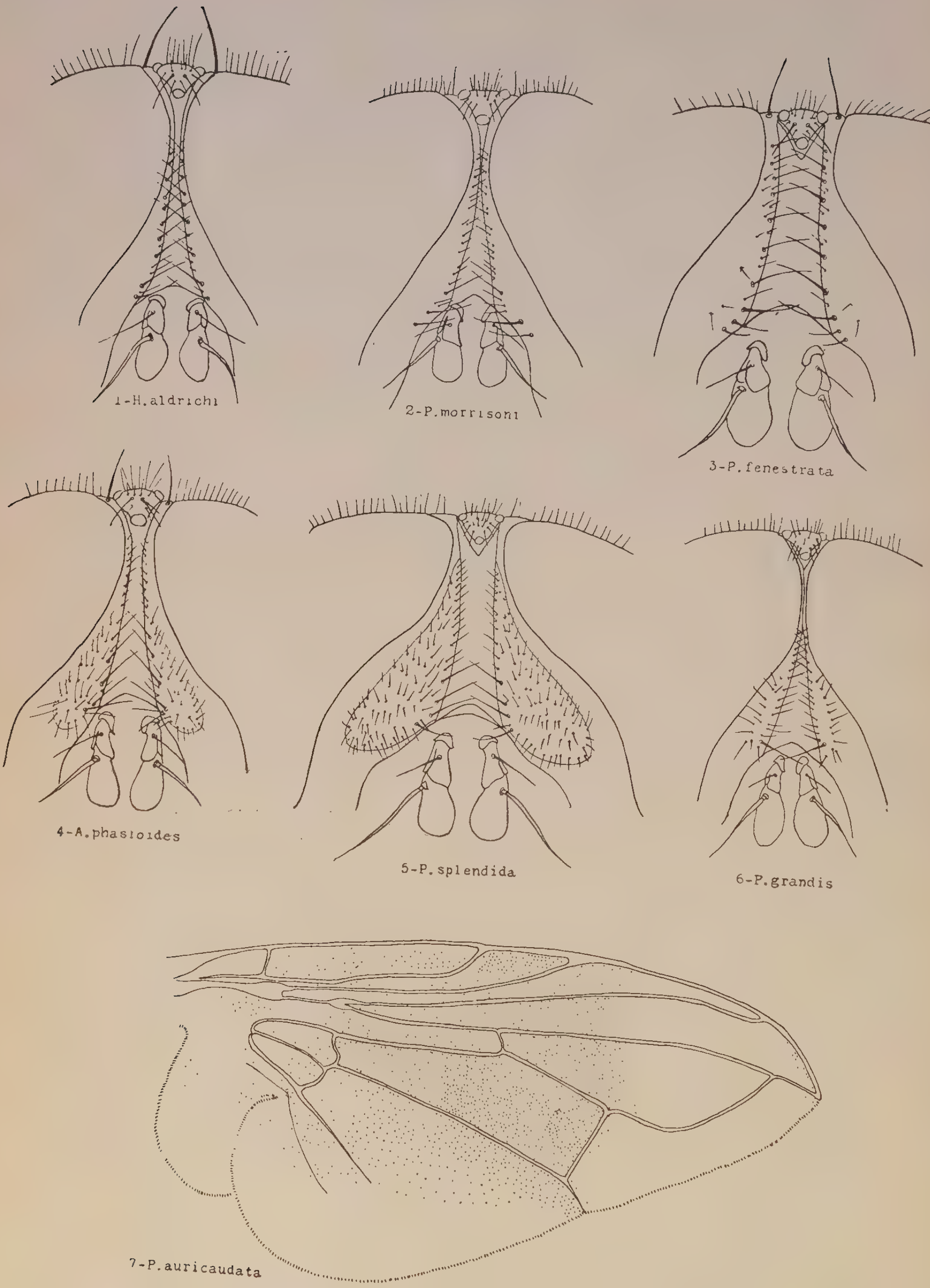
Colour characters of generic importance are found particularly in the male wing, the wings being whitish or not whitish, with markings which follow the wing veins, with markings which are confined to streaks without regard to the veins, or with the wing uniformly brownish or entirely clear. Characters of the pollinosity are found chiefly on the abdomen, the abdomen being covered with thick opaque pollen, with thin pollen, pollinose with shining spots, subshining or polished. It has been found that colour and pollinosity characters are some of the most reliable guides to the taxonomy of the whole complex.

Colour within a species appears to have a very different value to colour within a genus. In the species *Alophorellopsis purpurascens* TT., *Alophorella aeneoventris* Will. or in *Alophoropsis* species for example, the smaller specimens have a much poorer developed wing pattern in proportion to the total size than do the larger specimens, and in forms with broadened male wings, the ratio of the wing width to the wing length diminishes as the specimens become smaller. Thus in one species it is possible to have small specimens with clear, narrow wings along with large specimens with broad pictured wings.

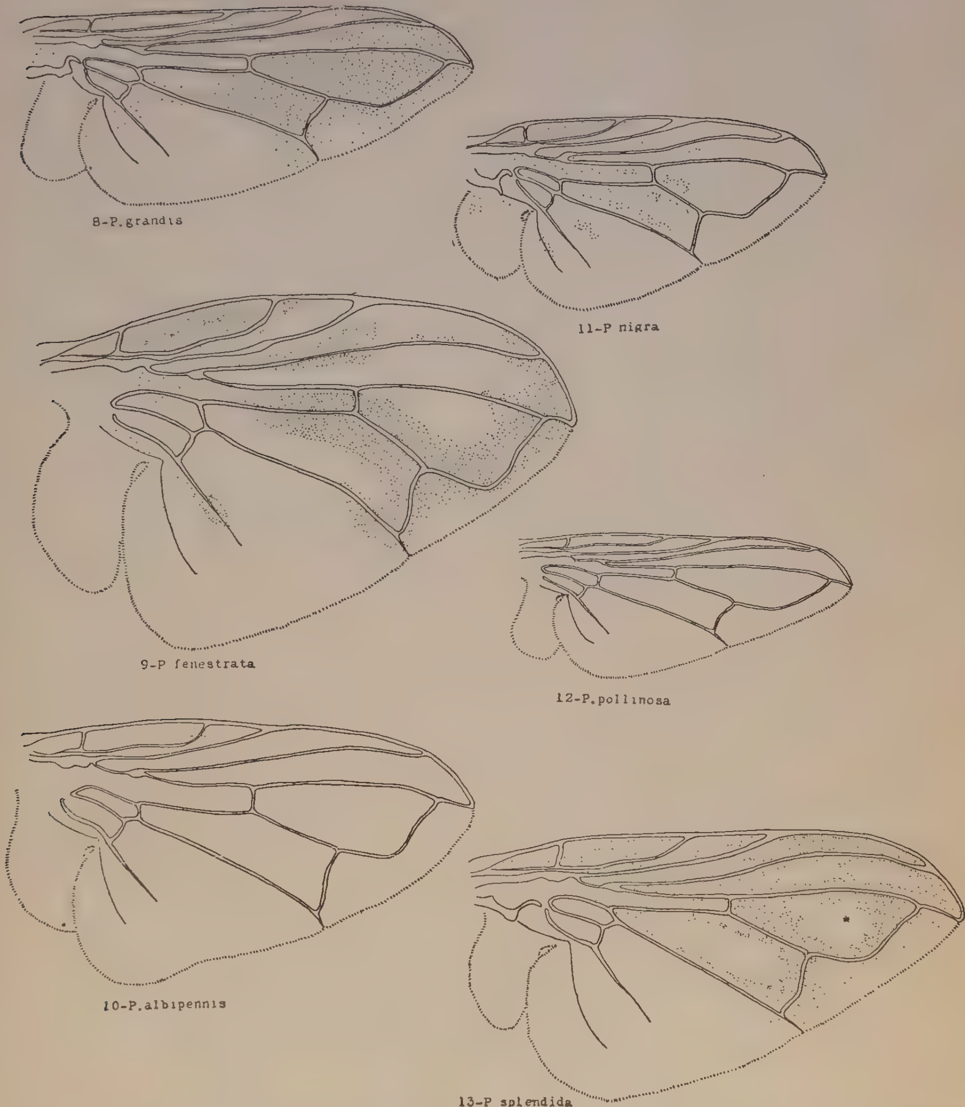
One of the great difficulties encountered, particularly in the *Alophorella* division will be the determination of the females. This sex lacks the characteristic wing shapes and wing patterns found in the males, and the pollinosity of the abdomen tends to conform to one type. For this reason it should be made clear that the separation of the genera of the *Alophorella* division (the genera *Alophoropsis*, *Oedematopteryx*, *Euphorantha* and *Alophorella*) has been based on male characters not possessed by the female.

ACKNOWLEDGMENTS

The writer wishes to express thanks to the following persons for supplying him with specimens and information: to Professor N. Banks of the Museum of Comparative Zoology; to Drs. C. F. W. Muesebeck and M. T. James of the United States National Museum; to Dr. H. H. Ross of the Illinois State Museum; and H. J. Reinhard to whom a special debt is owed for providing many notes and information concerning types.



FIGURES 1-6. Male heads, dorsal view. Drawn to approximately the same size regardless of scale. 7. Male wing.



FIGURES 8-28. Male wings. Figures 7-24 are drawn to the same scale while Figures 25-28 are somewhat enlarged.

KEY TO THE NORTH AMERICAN GENERA

1. Vertex over one-third head width in both sexes, the front equibroad; epistoma very short, about half as long as the clypeus; front without additional rows of hairs outside the frontal row but with three or four small, proclinate, orbital-like hairs, Tropical.. *Heyneophasia* Townsend

   Vertex less than a fourth as wide as the head; epistoma as long as the clypeus.... 2

2. Two strong sternopleural bristles; epistoma perpendicular, not warped forward; parafrontals contiguous in both sexes (fig. 6); petiole of apical cell short, less than one-fifth as long as the preceding section of R_5, the cubitulus very obtuse.. *Paraphorantha* Townsend

   Less than two sternopleurals *or* the epistoma strongly warped forward........... 3

3. Eyes separated by a distance greater than the width of the ocellar triangle (figs. 3, 5); frontalia very broad, at most slightly narrowed posteriorly; head very wide and flat; male wings generally whitish, pictured with brown; petiole of the apical cell generally less than one-fourth the length of the preceding section of R_5......... 4

   Eyes separated by a distance less than the width of the ocellar triangle, the frontalia well narrowed posteriorly; head more rounded, not flattened across the top; petiole of the apical cell one-fourth to one-half the length of the preceding section of R_5.. 6

4. No sternopleural bristle; pleura and notum very heavily yellow haired; epistoma nearly perpendicular, only slightly warped forward; parafrontals with many rows of hairs outside the frontal row anteriorly; petiole of the apical cell about one-seventh as long as the preceding section of R_5, the apical crossvein joining R_5 at an acute angle; piercer curved upwards, the sheath not flanged (*Alophora* R-Desvoidy), Europe.. *Phasia* Latreille

   One sternopleural bristle; epistoma strongly warped forward; petiole of the apical cell about one-fourth the length of the preceding section of R_5; piercer sheath flanged or curved downwards.. 5

5. Many additional rows of hairs present outside the frontal row anteriorly; wings only slightly widened in the male; male abdomen highly polished; piercer pointing downwards.. *Phasiomyia* Townsend

   No additional rows of hair outside the frontal row; male wings generally very broad and the abdomen pollinose; piercer pointing upwards............ *Paraphasia* Townsend

6. One or more rows of hairs outside the frontal row anteriorly (fig. 4); petiole of the apical cell one-fourth to three-eighths the length of the preceding section of R_5.. 7

   No hair strip outside the frontal row anteriorly (figs. 1, 2); petiole of the apical cell three-eighths to one-half as long as the preceding section of R_5................ 10

7. Male wings broad, the anal area enlarged and the costa strongly bulging or arcuate; fifth vein rarely reaching the wing margin; wings generally whitish, strongly marked with brown along the veins.. 8

   Male wings narrow, the anal area not particularly enlarged, the costa straight or slightly arcuate; fifth vein reaching the wing margin; wings not whitish, hyaline with brown stains which do not follow the wing veins....................... 9

8. Male abdomen heavily pollinose, the pollen dense, opaque, yellowish-grey.. *Oedematopteryx* Townsend

   Male abdomen shining or subshining, the pollen thin, greyish or bluish grey.. *Alophoropsis* Townsend

9. Abdomen brownish or greyish pollinose; vibrissae not well differentiated from the accessory vibrissae; wings nearly uniformly darkened; length 6-12 mm.. *Euphorantha* Townsend

   Abdomen shining or subshining, at least in the central region; vibrissae well differentiated; wings generally conspicuously stained with brown across the centre; length 3-6 mm.. *Alophorella* Townsend

10. Male wings broadened, at least in the anal area; colour whitish hyaline, marked with brown basally or along the veins; abdomen nearly round to elliptical, shining or thinly pollinose with distinct shining spots at the bases of the hairs or evenly pollinose.. 11

Male wings narrow; colour clear.. 12

11. Abdomen highly polished, at least centrally; cheeks one-third eye height; third vein bristled at the base; species 8-9 mm. long, Europe..............*Phorantha* Rondani

Abdomen more or less pollinose, usually punctate; cheeks one-sixth eye height; third vein with at most one small bristle at the base; species 2-6 mm. long.......................................*Alophorellopsis* Townsend

12. Presutural supraalar bristle absent; ocellar and vertical bristles absent or hair like; frontal bristles extending two or three below the anterior points of the frontalia; wings long, narrow and pointed; legs stout, the hind tibia of the male short, three-fourths to four-fifths as long as the femora, curved; piercer long, hooked up at the tip, the sheath flanged; third sternite of the female obsolete....*Phoranthella* Townsend

Presutural supraalar present; ocellar and vertical bristles present, strong or weak; frontal bristles stopping at the anterior points of the frontalia or one below..... 13

13. Seventh sternite of the female (piercer sheath) flanged, pointing downwards, the piercer pointing upwards; cheeks linear, mostly facing downwards (*Parallophora* Girschner), Europe.......................................*Hyalomya* R-Desvoidy

Seventh sternite of female not flanged, closely appressed to the piercer which points upwards; cheeks at least distinct when viewed in profile.....*Hyalomyiopsis* n. gen.

DIVISION I—**Heyneophasia** and allies

The genus *Heyneophasia* Townsend (genotype *H. heynei* Townsend, Costa Rica) has not been recovered from North America, north of Mexico, but in the tropical and subtropical regions from Mexico to Northern Argentina the various species appear to form a large part of the *Phasia* complex. From the descriptions it appears evident that Van der Wulp's *Hyalomyia munda*, *villosa*, *hebes*, *ochriceps* and *argenticeps* (9) belong either in *Heyneophasia* or a closely allied genus. Townsend also records *Hyalomya ecitonis* Townsend (1897) as being referable to *Heyneophasia*.

Front very broad, one-third to one-half head width in both sexes, the front and face equibroad; parafrontals without additional rows of hairs outside the frontal row, but with three or four short, proclinate hairs in a row; ocellars and verticals developed; epistoma about half as long as the clypeus, warped in the clypeal plane, extending but little below the vibrissae. Claws and pulvilli about half to three-fourths as long as the last tarsal segment. Wings narrow; petiole of the apical cell one-third as long as the preceding section of R_5; R_5 with one or two bristles at the base; wings clear. Abdomen round, mostly shining with transverse pollinose bands in the male, thinly pollinose in the female, quite hairy. Piercer curved up; sheath broad and stout, somewhat knobbed at the tip, slightly turned down.

DIVISION II—**Phasia** and allies

This division contains some of the largest and most striking of our Phasine flies. On account of their large size, coloured wings and the tendency to develop thick, yellow pleural hair, these forms are largely those which have been determined as *Alophora* spp. by American workers in recent years.

The genus *Phasia* Lat. (*Alophora R-Desvoidy*) in its restricted sense has not been recovered from North America. While Coquillett used the name *Alophora* in a very broad sense, his character (hairy front) excluded members of the genus *Paraphasia* TT. which have no additional rows of hairs on the front. Coquillett's member of that genus was placed in his genus *Phorantha* (as *nigrens* V. d. Wlp.).

In North America two well characterized genera are found, *Paraphasia* TT. and *Phasiomyia* TT., both genera being easily separated from each other and from the European *Phasia* by many definite characters. This relative ease of separation is in sharp contrast to that found in the *Alophorella* division in which the genera are poorly defined and highly variable.

Genus **Phasiomyia** Townsend

1915—*Phasiomyia* Townsend, Proc. Biol. Soc. Wash., XXVIII, 20; one species as *Alophora splendida* Coquillett (1902); Townsend, Manual of Myiology, VII, 67, 1938.

Length 6-8 mm. Black, the male abdomen highly polished; wings whitish, patterned with brown. Male head wide, flattened on top and the parafacials scooped out, the female front less flattened and the parafacials only slightly concave; eyes separated by a distance greater than the width of the ocellar triangle in the male (fig. 5), somewhat closer together in the female; frontalia wider than the parafrontals, equibroad; epistoma strongly warped forward, longer than the clypeus; parafacials wider than

the facialia, the two together equal to the width between the vibrissae; cheeks one-fourth to one-third eye height; ocellar and vertical bristles not differentiated; parafrontals with four to six additional rows of hairs outside the frontal row anteriorly, the hairs on a definite raised area; vibrissae weak; palpi long and enlarged apically. Acrostichals 0.1 (0.2); dorsocentrals 0.1 (1.2); intraalars 0.1; supraalars 1.1; lateral scutellars 2; sternopleurals 1. Wings narrow or slightly broadened, the costa straight or arcuate, the anal area enlarged; petiole of the apical cell just over one-fourth the length of the preceding section of R_5; 5R broad; cubitulus a rounded right angle; M_1 joining R_5 nearly at right angles. Legs robust; femora of male enlarged; hind tibia curved. Abdomen broad, flattened and pointed; sternites all well formed; piercer moderately wide, curved ventrally, extending beyond the sheath; sheath very broad, shovel-shaped, also curved ventrally.

Superficially the females of this genus resemble the females of *Alophorella* and allies to a marked degree while the males are typical of the *Phasia* division. The structure of the ovipositor, however, is very different from *Alophorella*. Townsend compared *Phasiomyia* to *Alophoropsis* but the relationship appears to be a distant one.

Only one species is known.

Phasiomyia spendida (Coquillett)

Alophora splendida Coquillett, Proc. U.S. Natl. Mus., XXV, 105, 1902, new name for *Alophora fenestrata* Bigot of Coquillett (1897) not of Bigot, 1889; type male, New Hampshire (U.S.N.M.).

Male. Antennae black; frontalia black; front dark grey, the pollen having a yellowish tinge; clypeus, epistoma, parafacials and cheeks slate grey, the cheeks yellow haired; palpi yellow.

Thorax dark; pleura, humeri, lateral line, prescutellar band and scutellum grey pollinose, the disc of the mesoscutum with a large patch of bright golden pollen, the rest of the mesonotum subshining black; pleural hairs yellow. Wings whitish hyaline or nearly clear, strongly or faintly marked with brown along the veins, the anal area and the posterior border whitish or clear (fig. 13); squamae brown, the lower half of the front scale whitish. Front femora with dense black hair dorsally, yellow hair ventrally; posterior femora with long, dense, black hair dorsally; claws and pulvilli very long.

Abdomen highly polished, purple to reddish, golden pollinose laterally and apically on the fourth segment, lightly greyish pollinose on the first segment; abdominal hair long, moderately dense, black on the dorsum, yellow on the venter.

Female. Generally smaller than the male; epistoma less projecting, the front narrower and the parafacials and cheeks narrower than in the male. Mesonotum dull black, the disc of the mesoscutum with a patch of brownish pollen; pleura mostly black haired. Wings narrow, clear, not marked with brown; veins yellow; squamae dark yellow. Legs black; femora not enlarged and without the characteristic hair patches of the male, wholly sparsely black haired. Abdomen subshining black, uniformly covered with greyish-yellow or brownish pollen which is evident when the abdomen is viewed from behind, the pollen thinner on the posterior edges of the segments and along the median line.

Distribution. ALBERTA (Slave Lake, Aug. 15-25): MAINE (Chamberlain Lake, Sept. 7; Mt. Katahdin, Aug.): NEW BRUNSWICK (Douglas, Aug. 7; Fredericton, Aug. 3): NEW HAMPSHIRE (Franconia, Sept.; White Mts.; Mt. Manodrock, Dec. 23; Base Mt. Wash., Aug. 21–Sept. 21; Kinsman Notch; Noxon Camp): NEW YORK (Oliverea, Sept. 3; Ithaca): NORTH CAROLINA (Mt. Mitchel, Aug. 22–Sept. 6): ONTARIO (Frater, Aug. 28; Algonquin Park; Lake Nipigon, July 23-28; Lake Abitibi, Aug. 15): PENNSYLVANIA (North Mt., Sept. 2): QUEBEC (Duchesnay, July 27; Bordeau, July 27; Awantjish, Aug. 4; Val. d'Espoir, Aug. 24-29; Cascapedia River, Sept. 6; Gaspe, Aug. 13): TENNESSEE (Smoky Mts., Sept. 1): VERMONT (Grand Isle, July 3; Peru, July 31): WASHINGTON (Seattle).

Genus **Paraphasia** Townsend

1915—*Paraphasia* Townsend, Proc. Biol. Soc. Wash., XXVIII, 20; one species as *Alophora fenestrata* Bigot (1889); Townsend, Manual of Myiology VII, 63, 1938.

Length 6-10 mm. Black; abdomen rounded, thinly pollinose; male wings generally broad, whitish, marked with brown. Head much wider than high, the front flattened and the parafacials scooped out; epistoma very long and strongly warped; eyes separated by a distance nearly equal to twice the width of the ocellar triangle in the male, slightly less in the female (fig. 3); frontalia about three times as wide as the parafrontals and nearly parallel-sided; parafacials much wider than the facialia, the two together narrower than the distance between the vibrissae; cheeks two-fifths eye height; ocellar and inner vertical bristles differentiated; no additional rows of hairs outside the frontal row anteriorly; vibrissae weak; palpi long and enlarged apically. Acrostichals 0.0; dorsocentrals 1.1; intraalars 0.1; supraalars 1.1; lateral scutellars 2; sternopleurals 1. Wings narrow to very broad, generally with an enlarged anal area and bulging costa in the male; petiole of the apical cell one-sixth to one-fourth the length of the preceding section of R_5; cubitulus generally a rounded right angle; M_1 joining R_5 at a right angle or nearly so. Abdomen broad and flattened; piercer heavy, short, slightly curved up; piercer sheath heavy, blunt, curved ventrally at right angles to the piercer.

The North American species may be separated as follows:

1. Legs entirely black 2
   Legs at least partly reddish; male wings whitish, pictured with brown. .*fenestrata* (Bigot)

2. Abdomen black with distinct bands of grey pollen; wings not whitish but transparent, the costal cell and the basal cells coloured with brown, leaving the apical third of the wing entirely clear; cubitulus at a marked obtuse angle................*nigra* n. sp.
   Abdomen mostly reddish, without distinct bands of pollen; male wing strongly whitish, the costal cell slightly brownish; cubitulus nearly a right angle.....*albipennis* n. sp.

Paraphasia fenestrata (Bigot)

Alophora fenestrata Bigot, Ann. Soc. Ent. Fr., VIII, 255, 1889; type male, Nevada (Newmarket ?).

Phorantha bidwelli Hine, Ohio Naturalist, II, 229, 1902; type male, Kansas (Ohio State U.); Townsend, Ins. Ins. Mens., IV, 128, 1916, synonymy.

Alophora magnapennis Johnson, Psyche, XI, 19, 1904; type, male, Montreal, Quebec (M. C. Z.): NEW SYNONYMY.

Phasia phasiatrata Smith, Psyche, XXII, 98, 1915; type, female, New Hampshire (U.S.N.M.); Townsend, Ins. Ins. Mens., IV, 128, 1916, synonymy.

Male. Length 8-10 mm. Antennae black, the second segment brownish, the third segment small and rounded, the second segment four-fifths as long as the third; arista thickened one-fourth way; frontalia dark reddish; front yellowish; clypeus, parafacials and cheeks grey; occiput grey with white hairs; palpi yellow.

Thorax dark; pleura, humeri, lateral line and the apical three-fourths of the scutellum greyish pollinose; mesonotum heavily golden-yellow pollinose with four darker vittae, the central pair found in front of the suture; pleural hair white, yellow or black. Wings very broad across the base (fig. 9), the costa strongly bulging and the anal area enlarged; colour whitish, strongly marked with brown in the costal region and along the veins, and with a distinct white mark extending from the costa to the centre of the discal cell; discal cell broad; cubitulus at right angles, the apical cross vein joining R_5 at right angles; squamae wholly dark yellow or whitish in the central region. Legs reddish-yellow, the tarsi darker; femora not particularly enlarged, the hind tibiae slightly curved; femora clothed posteriorly with yellow hair, dorsally with black hair.

Abdomen nearly round, wider than the thorax and flattened, the genital segment clearly visible from above; colour wholly red or mostly black with a narrow reddish margin; dorsal abdominal hair short, thin and black, closely appressed; lateral and ventral hair long, dense, erect and yellow.

Female. Eyes separated by a distance equal to one and a half times the width of the ocellar triangle, the frontalia widening in front. Abdomen black, wholly brownish-yellow pollinose, the pollen thinner on the posterior fourth of segments one to three. Wings narrow, entirely clear. Otherwise except for sexual differences as in the male.

Distribution. DISTRICT OF COLUMBIA (Rock Creek, April 28-May 1): KANSAS (Lawrence): NEW YORK (Ithaca, May; Caroline, May 6): NORTH CAROLINA (Raleigh, April 2): ONTARIO (Ottawa, May 24; Constance Bay, May): PENNSYLVANIA (North Mt., June 7): QUEBEC (Hull, May; Aylmer, April 20; Laniel, May 24; Rigaud, May 29; St. Hilaire, May 21): VIRGINIA (Vienna, April 7; U. of Richmond, May 1): WASHINGTON (Seattle, April 8).

Paraphasia albipennis n. sp.

Male. Length 10 mm. Antennae black, the second segment reddish; lunule shining black; the rest of the head, including the frontalia, heavily greyish pollinose; cheek and occiput white haired; vertex one-sixth head width; frontalia as broad as the ocellar triangle, slightly widened anteriorly; clypeus moderately and evenly concave; epistoma just projecting beyond the antennal prominence.

Thorax dark; pleura, lateral line and the apical half of the scutellum greyish pollinose; mesonotum and the basal half of the scutellum golden pollinose, the mesonotum showing four broad vittae, the central pair present before the suture; pleural hair white and yellow. Wings slightly widened at the base, the costa arcuate but not strongly bulging (fig. 10); colour entirely whitish, yellow at the base and with a dark brown spot at

the tip of the subcosta; cubitulus at a slight obtuse angle, the apical cross-vein entering R_5 nearly at right angles; squamae white with a yellow border. Legs wholly black, the femora with long white hair posteriorly.

Abdomen mostly reddish, with the incisures and a broad median vitta black; lightly grey pollinose on the first segment and on the lateral edges of the following segments and in the central region; abdominal hairs fine, black on the dorsum, yellow on the venter.

Holotype. ♂, Saskatoon, Sask., 2.V.1940 (A. R. Brooks): No. 5588 in the Canadian National Collection, Ottawa.

Paraphasia nigra n. sp.

Male. Length 8 mm. Antennae black, the second segment reddish; frontalia black; front greyish pollinose with a faint golden tinge; clypeus, parafacials, cheeks and occiput silvery grey pollinose; cheeks and occiput white haired; vertex one-sixth head width; epistoma evenly warped, the oral margin axis just longer than the antennal axis.

Thorax dark; pleura, humeri, lateral line and scutellum greyish pollinose; mesonotum golden-yellow pollinose with four distinct vittae, the central pair short; pleural hairs yellow or white. Wings narrow, slightly enlarged on the anal area, the costa straight, not bulging or arcuate (fig. 11); colour transparent, slightly whitish in the cells, marked with brown on the basal two-thirds, the brownish colour rather faint except in the costal cell; petiole of the apical cell two-sevenths as long as the length of the preceding section of R_5; cubitulus broadly obtuse; M_1 joining R_5 at an acute angle; squamae dark brown, the lower half of the front scale white. Legs dark brown to black, uniformly coloured, the front and mid femora white haired posteriorly.

Abdomen wholly black, grey pollinose, the pollen covering the abdomen except on the narrow posterior edges of the segments which are shining black; abdominal hair black, each hair with a small shining spot at its base.

Female. Head as in the male but the front slightly narrower and the epistoma not so protuberant. Thorax black, lightly covered with greyish pollen; mesonotum greyish pollinose with four darker vittae. Wings narrow, entirely clear; squamae white, the anterior scale somewhat yellowish. Abdomen black with grey pollen on the anterior three-fourths of segment two, three and covering segment four except for the extreme tip; segment one, the posterior fourth of segments two and three and a faint central vitta shining black. Otherwise except for sexual differences as in the male.

Holotype. ♂, Ukian, California, 31.3.30 (C. C. Wilson); in the United States National Museum, Washington.

Allotype. ♀, Los Angeles Co., California, April (Coquillett), labelled "*Phorantha nigrens* Wlp." and "*Phorantha ? occidentalis* Wlk. typical"; in Washington.

Paratype. ♂, Knight's Lndg., California, 2.IV.32; in H. J. Reinhard's collection, College Station, Texas.

DIVISION III—Paraphorantha and allies

Members of this division are largely tropical or subtropical, only three species of *Paraphorantha* being recorded from United States.

Genus **Paraphoranta** Townsend

1915—*Paraphorantha* Townsend, Proc. Biol. Soc. Wash., XXVIII, 20; one species as *Alophora grandis* Coquillett (1897): Townsend, Manual of Myiology VII, 64, 1938.

Length 6-12 mm. Black, thinly greyish or yellowish pollinose; wings narrow. Head rotund; eyes large, nearly touching or very narrowly separated in both sexes (fig. 6); epistoma not warped forward, nearly vertical; frontal bristles weak and short, the parafrontals with an additional row of hairs outside the frontal row anteriorly; ocellar and vertical bristles absent; parafacials one and a half times as wide as the facialia, the two together as wide as the distance between the vibrissae; cheek one-sixth eye height. Acrostichals 0.1 (0.2); dorsocentrals 0.1 (1.1 or 1.2) intraalars 0.0 (0.1); supraalars 1.1; sternopleurals 2; lateral scutellars 2. Wings narrow in both sexes, pointed; petiole of 5R one-eighth to one-sixth as long as the preceding section of R_5; cubitulus very obtuse, the apical crossvein entering R_5 at an acute angle. Abdomen oval, evenly rounded, subshining with thin whitish or yellowish pollen. Legs normal, the tibiae and femora straight; claws and pulvilli very long in the male. Piercer narrow, curved upwards; piercer sheath long, two and a half times as long as the preceding sternite, curved upwards hiding the piercer.

The three North American species may be separated as follows:

1. Species 6-7 mm. long; abdomen black, distinctly yellowish-grey pollinose in the female, the male with broad brown bands on each segment or nearly uniformly brownish black; pleural hair black or yellowish .... *pollinosa* n. sp.
   Species 9-12 mm. long; abdominal pollen not conspicuous in the female, the male with only one brown band at the most 2
2. Pleural hair white or yellowish; posterior two segments of the abdomen thinly golden pollinose in contrast to the greyish pollinose anterior segments; mesonotum rather distinctly vittate .... *auricaudata* n. sp.
   Pleural hair black; abdomen subshining black, thinly whitish pollinose, the male with a brown band on segment two .... *grandis* (Coquillett)

Paraphorantha grandis (Coquillett)

Alophora grandis Coquillett, Rev. Tach., 45, 1897; type female, Lufkin. Texas (U.S.N.M.).

Male. Length 9-10 mm. Antennae black, the second segment reddish; arista long, tapered from base to apex; frontalia reddish, pinched out in front of the ocelli; parafrontals greyish with a faint yellowish tinge; parafacials and cheeks golden yellow; epistoma denuded; occiput grey with white hairs; palpi enlarged apically, dark yellow, strongly haired.

Thorax dark, subshining on the disc; humeri, lateral line and the apical half of the scutellum more noticeably grey; a pair of short, narrow, brownish vittae on the prescutum; basal half of the scutellum and a narrow band on the mesonotum just posterior to the suture dark brown; postscutellum and pleura grey pollinose; pleural hair black. Wings narrow and pointed; colour uniformly brownish to nearly clear (fig. 8); squamae brown, the lower half of the top scale white. Legs black or dark brown.

Abdomen subshining black, the greyish-white pollen thin; anterior half of the basal segment, a broad band on the anterior half of the second segment and a small median spot on segments three and four brown.

Female. Head similar to the male; mesonotum uniformly thinly grey pollinose. Wings clear; veins yellowish; squamae yellowish. Abdomen subshining black, very thinly coated with whitish pollen, the pollen more evident on the posterior half of the second segment, on the anterior edges of the segments and laterally.

Distribution. GEORGIA (Stone Mt., Nov. 17): ILLINOIS: MASSACHUSETTS (Melrose Hghds., Sept. 13; Forest Hills, Sept. 12): MISSISSIPPI (Agr. Coll., April 6): NORTH CAROLINA (Raleigh, late Oct.): TEXAS (College Station, Nov. 3; Willis; Lufkin): VIRGINIA (Great Falls, Oct. 8; Upton, July 2).

Paraphorantha pollinosa n. sp.

Male. Length 7 mm. Antennae black, the second segment reddish; frontalia black; parafrontals greyish with a faint yellowish tinge; parafacials and cheeks yellow; occiput grey with white hairs; palpi dark yellow.

Thorax black, lightly grey pollinose on the humeri, lateral line, pleura and on the apical half of the scutellum, thinly yellowish pollinose on the prescutum; vittae distinct when viewed from behind; pleural hair mostly yellow, occasionally black or partly black. Wings nearly clear, lightly brown fumose (fig. 12); veins brown; squamae dark brown, the anterior scale whitish on the lower half. Legs black.

Abdomen dark, subshining; anterior half of the first segment without pollen, the posterior half brownish; segments two, three and four brownish pollinose centrally, greyish laterally, the pollen very thin, only becoming evident when the abdomen is viewed from behind.

Female. Head similar to the male; frontalia dark reddish to black. Pleural hair mostly yellow with intermixed black hair above; mesonotum conspicuously greyish white pollinose, four broad, darker vittae being evident. Wings clear; squamae white. Abdomen dark, conspicuously yellowish-grey pollinose, the pollen somewhat thinner on the posterior fourth of the segments and along the median line.

Holotype. ♂, Chesapeake Beach, Md., 20.IX.14 (C. T. Greene); in the Museum of Comparative Zoology, Cambridge.

Allotype. ♀, same data as holotype.

Paratypes. 6 ♂, 5 ♀, Chesapeake Beach, Md., 21.IX.–, 18.IX.– (N. Banks) in Cambridge. 1 ♂, College Station, Texas, 5.21.19 (H. J. Reinhard), 1 ♀, College Station, Tex., April 21, 1939 (H. Menusan) "a parasite of *Chlorachroa ligata* Say," 1 ♀, Winter Haven, Tex., 5.21.1936 (S. E. Jones) in H. J. Reinhard's collection. 1 ♀, Anacostia, D. C., 24.9.14 (R. C. Shannon), 1 ♂, Bennings, D. C., 10.22.14 (R. C. Shannon), 1 ♀ Beltsville, Md., July 9, 1916 (W. L. McAtee), 1 ♂, 2 ♀, Chesapeake Beach, Md., 21.IX.–, 19.VII.20 (N. Banks, Bridwell), 1 ♀, Grove Hill, Md., 20.IX.16 (C. H. Townsend), 1 ♂, Santa Clara Co., Cal. (Baker) in the United States National Museum.

Paraphorantha auricaudata n. sp.

Male. Length 11 mm. Antennae black; frontalia brownish; front silvery-grey pollinose, the parafacials and cheeks golden; occiput dark grey with pale yellow hairs; palpi yellow.

Thorax black, the mesonotum with conspicuous grey pollen; four very broad non-pollinose vittae extending from the head to the scutellum, these vittae about four times as broad as the pollinose strips between them; scutellum grey pollinose, shining at the base; pleura grey pollinose, pleural hair yellow. Wings broad, the costa slightly arcuate but not bulging (fig. 7); petiole of the apical cell about one-fifth the length of the preceding section of R_5; basal two-thirds of the wing dark brown, the apical one-third hyaline except the extreme tip of R_5 which is brownish; veins brown, bordered with brownish-yellow rays; squamae brown, the lower half of the front scale lighter in colour. Legs black, the tibiae brownish; front femur with yellow hair posteriorly.

Abdomen broad and long, subshining; segments one and two thinly whitish-grey pollinose, the pollen more evident laterally and on the basal half of the first segment; posterior two segments thinly golden pollinose; abdominal hair black on the dorsum, yellow on the venter.

Female. Head similar to the male, the parafacials and cheeks greyish with a slight golden tinge; occipital ruff white. Thorax as in the male, the greyish pollen being somewhat denser and the vittae narrower; sterno-pleural hairs yellow, the mesopleural hairs black. Wings clear; veins brown; squamae white with a yellowish tinge. Abdomen rather strongly pollinose, especially posteriorly; anterior two abdominal segments thinly greyish pollinose, the posterior two golden pollinose.

Holotype. ♂, Milton, Oregon, June 22, 1938 (K. Gray and J. Schuh); in H. J. Reinhard's collection, College Station, Texas.

Allotype. ♀, Cuchara, Colorado, 8.7.1940 (F. Snyder).

Paratypes. 1 ♀, Yakima, Wash., Aug. 27, 1931 (A. R. Rolfe) in Reinhard's collection. 1 ♂, Mt. Moscow, Idaho, VI.24 (J. M. Aldrich) in the United States National Museum. 1 ♂, Springdale, Ark., Aug. 1933, 1 ♂, Colton, Cal., 10.13 (F. A. Eddy) in Cambridge.

DIVISION IV—Alophorella and allies

The four North American genera which belong in this division are particularly difficult to deal with. The genera have been founded on outstanding species which have certain weak morphological characters in chaetotaxy, body form and wing shape, but these species appear to represent only one end of the variation within the genus, species at the other end of the variation being much more difficult to place. The weak morphological characters are, however, strongly supported by colour characters, extent of pollinosity, general size and male wing form and it is in the *Alophorella* division that this type of character is particularly useful. The females appear to possess no characters of value to separate them either generically or specifically.

Genus **Alophoropsis** Townsend

1915—*Alophoropsis* Townsend, Proc. Biol. Soc. Wash., XXVIII, 20; one species as *Alophora phasioides* Coquillett (1897): Townsend, Manual of Myiology VII, 39, 1938.

Length 5-10 mm. Black with thinly pollinose or shining abdomen and broad whitish, usually pictured wings. Head quadrate, wider than high; flat front longer than the face; clypeus gently concave; epistoma as long as the clypeus, projecting, the oral margin axis slightly longer than the antennal axis; parafacials flat, one and one-half times as wide as the flattened facialia, the two together equalling three-fourths the distance between the vibrissae; eyes separated by a distance slightly less than the width of the ocellar triangle; frontalia distinct throughout, slightly widened anteriorly (fig. 4); vertical and ocellar bristles hair like, hardly distinguishable; parafrontals with two or three rows of hairs outside the frontal row anteriorly; frontal row extending well below the anterior points of the frontalia; facialia bristled on the lowest third; vibrissae strong and well differentiated; cheek one-fifth to one-sixth eye height. Acrostichals 0.1, very weak; dorsocentrals 0.1; intralars 0.1, very weak; supraalars 1.1; lateral scutellars 2; sternopleurals 1. Male wings very broad basally, the costa strongly bulging; petiole of 5R one-fourth to three-eighths the length of the preceding section of R_5; cubitulus rounded; M_1 joining R_5 at right angles; C_1 generally not reaching the margin of the wing. Legs stout but femora not particularly enlarged; claws and pulvilli of male very long. Abdomen broad and flattened in the male, less so in the female; abdominal hair short, semierect. Piercer narrow, slightly curved upwards; sheath shallow, also curved upwards, covering the piercer except at the tip.

The North American species may be separated as follows:

1. Wings whitish hyaline without brown markings; abdomen with a pronounced brassy tinge; length 6 mm. . . . . *nitida* (Coquillett)
   Wings pictured with brown or black 2

2. Abdomen greyish pollinose, the pollinosity at times quite thin; wings heavily patterned with brown or nearly clear . . . . *phasioides* (Coquillett)
   Abdomen polished purple, at least in the central region 3

3. Anterior three-fourths of the wing very dark, the white marking in the cells very faint; wing markings black; length 7 mm. . . . . *alaskensis* n. sp.
   Anterior three-fourths of the wing with a definite pattern of white and brown, the central region of the cells strongly whitish; wing markings brownish; length 4-6 mm. . . . . *occidentalis* n. sp.

Alophoropsis nitida (Coquillett)

Alophora nitida Coquillett, Rev. Tach., 45, 1897; type male, Virginia (U.S.N.M.).

I have not seen this species and so can only repeat the original description. It seems probable that this form and *phasioides* are the same, *phasioides* being quite variable with smaller specimens possessing nearly clear wings.

"Males; black, the palpi yellow, abdomen with a pronounced brassy tinge, shining, thinly white pollinose; thorax when viewed from behind thinly white pollinose except the front end and two subdorsal vittae behind the suture; eyes separated as widely as the posterior ocelli, calypteres

greyish white, wings whitish hyaline, base to tip of second basal cell yellow, costa strongly arcuate, last section of third vein nearly half as long as the preceding section; length 6 mm. Potomac Creek, Virginia. A single male specimen collected May 23, 1896 by C. W. Johnson."

Alophoropsis phasioides (Coquillett)

Alophora phasioides Coquillett, Rev. Tach., 46, 1897; type male, Franconia, New Hampshire (U.S.N.M.).

Male. Length 6-10 mm. Antennae black, the second segment obscurely red tipped; head greyish pollinose, the front generally with a yellowish or golden tinge; cheeks and occiput white haired; palpi yellow.

Thorax black, thinly greyish pollinose; mesonotum with four darker vittae, the vittae narrow and well defined on the prescutum, very broad, short and only narrowly separated on the mesoscutum; pleural hair mostly black, humeral hair yellow. Wings very broad, the costa strongly bulging and the anal area enlarged (fig. 15); colour whitish, strongly marked along the veins with broad brown bands, the area just beyond the tip of R_1 extending from the costa to the middle of the discal cell having a tendency to be whitish, the brown vein markings in this area narrower, sometimes entirely lacking; veins yellow; squamae yellowish, the lower half of the front scale white. Legs black, the front and hind femora with yellow hair posteriorly.

Abdomen black, subshining, uniformly covered with thin greyish pollen or at times a somewhat darker median vitta present; abdominal hairs semierect, short and black dorsally, long, erect and yellow laterally and ventrally.

Small specimens of the species tend to have the brown colouring of the wing more diffuse and fainter than the larger specimens.

Distribution. MASSACHUSETTS (Melrose Hghds., June 11; Holliston, July 14); NEW HAMPSHIRE (Franconia); NEW YORK (Dix Hills, L.I., June 15); ONTARIO (Ottawa, July 14); QUEBEC (Aylmer, Oct. 5; Abbotsford, Sept. 20; Rigaud, Oct. 11).

Alophoropsis alaskensis n. sp.

Male. Length 7 mm. Antennae and arista wholly black; frontalia black; head entirely greyish pollinose, the anterior half of the front somewhat darker; cheeks and occiput with white hair; palpi yellow or brown.

Thorax black, black haired, thinly greyish pollinose; mesonotum with four broad darker vittae, these narrower and separated in front of the suture but coalescing behind. Wings very broad, the costa strongly bulging and the anal area enlarged (fig. 14); colour whitish, strongly marked with black along the veins, yellowish at the base, the centre of cells 5R and 1M a little lighter in colour, the anal area without dark markings; veins black; squamae translucent, the upper scale whitish on its lower half. Legs black, the femora with black and yellow hair posteriorly.

Abdomen dark, mostly shining purple in the central region; the segments laterally, the posterior third of the third segment and the whole of the fourth and fifth segments with greyish pollen, the pollen very thin except at the margin of the abdomen; abdominal hairs semierect, long and black dorsally, yellowish ventrally.

Female. Wings narrow, entirely clear, yellowish at the base; veins mostly yellow; squamae white, a little yellowed laterally. Abdomen black; the first abdominal segment, a narrow median vitta on segments two and three and the extreme posterior margins of segments two and three without pollen, the rest of the abdomen thinly greyish pollinose, the pollen somewhat browner centrally; abdominal hair black, moderately long. Otherwise except for sexual characters similar to the male.

Holotype. ♂, Matanusta, Alaska, 27.8.1943; in the United States National Museum, Washington.

Allotype. ♀, same data as type.

Paratypes. 1 ♂, 3 ♀, same data as type.

Alophoropsis occidentalis n. sp.

Male. Length 5-6 mm. Antennae black, the second segment somewhat reddish apically; frontalia black to reddish; front, face, cheek and occiput greyish pollinose, the pollen without a yellowish shade.

Thorax dark, thinly greyish pollinose; mesonotum with four darker vittae, the vittae narrow and separated on the prescutum except in front, very broad and confluent on the mesoscutum; pleura black haired. Wings very broad, the anal area enlarged and the costa bulging (fig. 16); colour whitish, strongly marked with brown along the veins, the centres of 5R and 1M whitish; squamae white, the posterior scale with a faint brown mark centrally. Legs black, the femora with white hair posteriorly.

Abdomen mostly shining purple, thinly greyish pollinose around the margin and at the apex; at times the pollinosity is quite extensive covering all but a small area of the abdomen centrally; abdominal hairs long, semi-erect, black dorsally, yellowish-white laterally and ventrally.

Holotype. ♂, White Mts., New Mexico, NFk Ruidoso, about 8200 ft., on flowers of *Solidago trinervata*, 8-17 (Townsend); in the United States National Museum, Washington.

Paratypes. 1 ♂, same data as type, 1 ♂, Vernon, B.C., 20.IX.1918 (M. K. Ruhmann) in Washington. 1 ♂, Waterton, Alta., July 11, 1923 (H. L. Seamans), 1 ♂, Lethbridge, Alta., July 10, 1922 (H. L. Seamans) in the Canadian National Collection, Ottawa. There are also several broken specimens in the Canadian National Collection from the type locality, Slave Lake, Alta., Aug. 14, 1924; Mozart, Sask., Sept. 12, 1937; Brant, Alta., Aug. 5, 1929 and Bozeman, Mont., Sept. 8, 1916.

Genus **Oedematopteryx** Townsend

1916—*Oedematopteryx* Townsend, Proc. U.S. Natl. Mus., XLIX, 633; two species, including *Alophora pulverea* Coquillett (1897), genotype by original designation; Townsend, Manual of Myiology VII, 60, 1938.

Length 5-7 mm. Narrowed, abdomen heavily yellowish-grey pollinose; wings broadened in the male. Head one-third wider than high; flat front longer than the face; clypeus gently concave; epistoma as long as the clypeus, projecting, the oral margin axis slightly longer than the antennal axis; parafacials not scooped out, twice as wide as the flattened facialia, the two together three-fourths as wide as the distance between the vibrissae;

eyes separated by a distance slightly less than the width of the ocellar triangle; frontalia distinct, widened anteriorly; vertical and ocellar bristles hair like; parafrontals with two or three rows of hairs outside the frontal row anteriorly; facialia bristled on the lowest third to half; vibrissae well differentiated from the accessory vibrissae; cheek one-fifth to one-sixth eye height. Acrostichals 0.1; dorsocentrals 0.1 (1.1), the presutural when present very fine; intraalars 0.1, very weak; supraalars 1.1; lateral scutellars 2; sternopleurals 1. Male wings very broad, enlarged in the anal region, the costa bulging; petiole of 5R one-fourth the length of the preceding section of R_5; cubitulus a rounded right angle; M_1 joining R_5 nearly at right angles; C_1 rarely reaching the margin of the wing. Legs stout but the femora not particularly enlarged. Abdomen rather narrow, flattened in the male, very heavily and uniformly covered with yellowish-grey pollen; abdominal hairs moderately long, semierect.

The three North American species may be separated as follows:

1. Wings strongly whitish, marked with brown 2
   Wings clear or only slightly whitish, the brown colouring diffuse over the whole membrane although more concentrated along the veins and anteriorly; front with a strong yellowish or golden tinge to nearly grey .... *fumosa* (Coquillett)

2. Brown colouring along the veins very weak, usually confined to the anterior veins; front shining grey; squamae white, Western .... *opaca* (Coquillett)
   Wings strongly marked with brown especially in the costal region; front usually with a golden or yellowish cast; squamae partly yellowish, Eastern.... *pulverea* (Coquillett)

Oedematopteryx pulverea (Coquillett)

Alophora pulverea Coquillett, Rev. Tach., 46, 1897; type male, Ontario (U.S.N.M.).

Male. Length 6-7 mm. Antennae black or the second segment reddish; frontalia black; front grey, usually with a very strong golden or yellowish tinge, rarely silvery grey; face, cheeks and occiput silvery grey; palpi yellow.

Thorax dark, lightly grey pollinose; mesonotum showing four darker vittae, the vittae joined together anteriorly, separated posteriorly, the darker markings of the prescutum bordered with greyish pollen next the suture; on the mesoscutum the vittae are very broad, not separated, the central pair short; humeri and the anterior part of the mesopleura with yellow hair, a few hairs on the sternopleura also yellow. Wings very broad, the costa excessively bulging (fig. 19); colour strongly whitish with broad brown markings along the veins, this brown marking being very distinct in the costal and subcostal cells, along R_2, R_3 and R_5 and at the apex; veins yellow (this wing pattern is very variable, some specimens having nearly clear wings with only faint brown markings, other specimens having the brown bands bordering all the veins); squamae white with a yellow tinge centrally and on the upper scale. Legs black, femora with yellow or white hair behind.

Abdomen covered with heavy, opaque, yellowish-grey pollen with traces of a narrow vitta on segment one; abdominal hairs black on the dorsum, long, erect and yellow laterally and ventrally.

Distribution. CONNECTICUT (Colebrook, July 11); ILLINOIS: INDIANA (LaFayette, June 1–Oct. 19); MARYLAND (Grove Hill, Oct. 30; College Park, Oct. 30); MASSACHUSETTS (Amherst, June 18; Melrose Hghds.,

June 18–Aug. 18; Jaunton, Sept.; Agawam, Oct. 27; North Saugus, July 2); NEW BRUNSWICK (Barber, June 23–Aug. 3; Fredericton, Aug. 2); NEW HAMPSHIRE (Base Mt. Wash., Sept. 3; Kinsman Notch, July 7); NEW JERSEY (Del. W. Gap, July 12); ONTARIO (Lake Abitibi, July 19–Aug. 12; Brockville, Oct.; Simcoe, June 3); PENNSYLVANIA (Hazelton, Sept. 28); QUEBEC (Montreal, Oct. 13; Hull, Sept. 25; Aylmer, Sept. 28–Oct. 5; Knowlton, Aug. 6; Ladysmith, Aug. 6; Clarenceville, July 16); VIRGINIA (Falls Church, Sept. 20); WISCONSIN Milwaukee, Oct. 1).

Oedematopteryx opaca (Coquillett)

Alophora opaca Coquillett, Rev. Tach., 44, 1897; type male, Eastern Washington (U.S.N.M.).

Male. Length 5-6 mm. Antennae black; front, face, cheeks and occiput wholly silvery grey pollinose. Thorax dark, coloured as in *pulverea*. Wings broad, the costa bulging (fig. 17); colour whitish, faintly brown in the costal cell and at the apex; squamae white, slightly yellowish on the border. Legs black, the femora with white or yellow hair posteriorly. Abdomen uniformly and heavily yellowish-grey pollinose, the anterior half of the first segment and a narrow vitta on the first segment dark.

Distribution. ALBERTA (Waterton, July 14); BRITISH COLUMBIA (Vernon, Sept. 9; Trinity Valley, July 27); WASHINGTON.

Oedematopteryx fumosa (Coquillett)

Alophora fumosa Coquillett, Rev. Tach., 46, 1897; type male, New Jersey (U.S.N.M.).
Oedematopteryx fumosa (Coq.), Townsend, Proc. U. S. Natl. Mus., XLIX, 633, 1916.

Male. Length 4.5-6 mm. Antennae black; front greyish to strongly golden pollinose; face, cheeks and occiput grey. Thorax dark, coloured as in *pulverea*. Wings broad, the costa bulging but not strongly so (fig. 18); colour clear or very slightly whitish posteriorly, the brown colouring diffused over the whole membrane, making the wings comparatively dark, the costal region and veins more heavily bordered with brown; squamae white, brownish or yellow in the central region. Legs black, the femora with yellow or white hair posteriorly. Abdomen uniformly yellowish-grey pollinose with evidence of a dark vitta on segment one.

Distribution. ILLINOIS (Douglas, May 11); NEW MEXICO (White Mts., Aug. 17); NEW YORK (Wilmington Notch, July 1; Geneva, ex *Lygus caryae*); ONTARIO (Ottawa, Aug. 14; Simcoe, May 29–July 3; Orillia, June 10; Jordan, July 8); VIRGINIA (Potomac Creek, May 23; Falls Church, May 3–June 18).

Genus **Euphorantha** Townsend

1915—*Euphorantha* Townsend, Proc. Biol. Soc. Wash., XXVIII, 20; one species as *Alophora diversa* Coquillett (1897); Townsend, Manual of Myiology VII, 52, 1938.

Length 6-12 mm. Rather narrow; abdomen thinly pollinose; wings narrow, not whitish. Head one-third wider than high; flat front longer than the short face; epistoma long and warped, the antennal and oral margin axes equal; parafacials not scooped out, slightly wider than the flat facialia, the two together four-fifths as wide as the distance between the vibrissae; eyes narrowly separated by a distance slightly less than the

width of the ocellar triangle in the male, very narrowly separated in the female; frontalia distinct throughout although very narrowly so in the female; vertical and ocellar bristles present but fine; two or three rows of hairs outside the frontal row anteriorly; frontal bristles and hair strips extending well below the anterior points of the frontalia; vibrissae strong but not well differentiated from the accessory vibrissae; facialia bristled one-third to one-half way. Acrostichals 0.1; dorsocentrals 1.1 (1.2), the anterior fine; intraalars 0.1; supraalars 1.1; lateral scutellars 2; sternopleurals 1, occasionally 2; pleural hair black. Wings not widened, not whitish or having the veins margined with brown; petiole of 5R one-fourth to one-fifth as long as the preceding section of R_5; cubitulus broadly rounded; M_1 joining R_5 at a slight acute angle; C_1 reaching the margin of the wing. Legs normal, femora not particularly enlarged. Abdomen about as wide as the thorax, wholly pollinose; sternites all well formed; piercer moderately broad, curved dorsally; sheath shallow and broad, about as long as the preceding sternite, slightly curved dorsally.

The two North American species may be separated as follows:

Length 9-12 mm. Abdomen uniformly greyish-brown or greyish pollinose, somewhat darker on the median line and on the posterior edges of the segments; piercer sheath very heavy, boat shaped with a blunt tip........................*diversa* (Coquillett)

Length 6-7 mm. Abdomen greyish-white pollinose, the posterior third to half of the intermediate segments brownish, the banded effect being quite conspicuous in the male; piercer sheath narrow, very shallow, the tip pointed......*subopaca* (Coquillett)

Euphorantha diversa (Coquillett)

Alophora diversa Coquillett, Rev. Tach., 45, 1897; type female, Massachusetts (U.S.N.M.).

Male. Length 10-12 mm. Antennae and arista black; frontalia black; palpi yellow; parafrontals heavily golden pollinose, the facialia golden next the vibrissae; face, cheeks and occiput silvery-grey, the cheeks with white hair.

Thorax dark, thinly grey pollinose; mesonotum with four broad, darker vittae, the vittae narrower and distinct on the prescutum, very broad and only narrowly separated on the anterior half of the mesoscutum; pleural hair black. Wings not whitish, hyaline, heavily coloured with brown especially on the anterior half and in the central region (fig. 20); squamae dark brown, the upper scale whitish on its lower half. Legs black; femora with some short white hair posteriorly.

Abdomen black, mostly opaquely greyish or yellowish-grey pollinose, the fourth segment generally more yellowish than the intermediate segments; first segment shining; a very narrow median vitta and the posterior edges of the intermediate segments subshining; abdominal hairs semierect, black on the dorsum and laterally, yellowish ventrally.

Female. Length 9-10 mm. Front silvery-grey or yellowish-grey pollinose. Wings entirely clear; veins yellow; squamae pale yellow. Abdomen black, the posterior segments heavily grey pollinose; first segment, a narrow median vitta and the posterior margin of segment two subshining. Piercer sheath particularly stout, boat shaped with a blunt tip. Otherwise as in the male.

Distribution. DISTRICT OF COLUMBIA (Washington, Oct. 14; Georgeton, Oct.); GEORGIA (Stone Mt., Nov. 17); ILLINOIS (Alto Pass, May 5; Makanda, Oct. 6); INDIANA (LaFayette, Oct. 9); MARYLAND (Grove Hill, Oct. 30; Glen Echo, Oct. 22); MASSACHUSETTS (Beverley, Oct. 11; Reading, Sept. 30); MISSISSIPPI (Agr. Col., April); NEW YORK (Oswego, Oct. 4); OHIO (Cincinnati, Sept. 25); ONTARIO (Jordan, Sept. 20; Apple Hill, Oct. 4); PENNSYLVANIA (Hazelton, Sept. 20); QUEBEC (Aylmer, Sept. 28; Hull, Aug. 26; Abbotsford, Sept. 20); TEXAS (College Station, Oct. 29); VIRGINIA (4-mile Run, Oct. 11; Great Falls, Oct. 23).

Euphorantha subopaca (Coquillett)

Alophora subopaca Coquillett, Rev. Tach., 47, 1897; type male, Woodbury, N.J. (U.S.N.M.)
Euphorantha subopaca (Coq.), Townsend, Manual of Myiology VII, 53, 1938.

Male. Length 5-7 mm. Antennae and arista black; front heavily golden or yellowish pollinose; face, cheeks and occiput grey.

Mesonotum mostly subshining black, the grey pollen very thin; vittae as in *diversa* but very ill-defined; pleural hair black. Wing not whitish, almost uniformly brown, sometimes with the central region darker (fig. 21); squamae dark brown. Legs black, the femora with black hair.

Abdomen black, mostly greyish-white pollinose; first segment, a narrow median vitta and the posterior edges of the intermediate segments without pollen; intermediate segments with a broad band of brownish pollen on the posterior half of each segment; abdominal hairs erect, fine, wholly black.

Female. The females average slightly smaller than the males; front greyish or yellowish-grey pollinose; wings entirely clear, veins yellow; squamae white or yellowed in the central region. Abdomen mostly greyish-white pollinose, the first segment and a narrow median vitta without pollen; posterior third of intermediate segments each with a brown pollinose band; piercer sheath very narrow and shallow, with a pointed tip; otherwise as in the male.

Distribution. DISTRICT OF COLUMBIA (Tennallytown, Oct. 27); ILLINOIS (White Heath, May 9; Douglas, May 9; Savannah, June 14); INDIANA (Elkhart; LaFayette, Oct. 19); MAINE (Bar Harbour, Aug. 2); MARYLAND (Chesapeake Beach, Sept. 17-25; Lakeland, Sept. 6; Grove Hill, Oct. 30; New Bedford); MASSACHUSETTS (Milton; Waquoit, Sept. 21; Wellesley, Oct. 1; Holliston, Oct. 6); NEW BRUNSWICK (Douglas, Aug. 17); NEW JERSEY (Riverton, Oct. 12-20; Westville, May 19); NEW YORK (Ithaca, July 31); ONTARIO (Ottawa, June 10; Jordan, July 11); PENNSYLVANIA (Manayunk; Montg. Co., July 4); QUEBEC (Aylmer, Oct. 5; Norway Bay, Aug. 24); SOUTH CAROLINA (Clemson, Oct. 11); VIRGINIA (Mt. Vernon, Sept. 30; Roselyn, May 1; 4-mile Run, Oct. 11; Potomac Creek, May 23); WISCONSIN (Milwaukee; Chicago, May 8–Sept. 7).

Genus **Alophorella** Townsend

1912—*Alophorella* Townsend, Proc. Ent. Soc. Wash., XIV, 45; one species as *Thereva obesa* Fabricius (1798); Townsend, Manual of Myiology VII, 36, 1938.

European systematists have had considerable difficulty in coming to an agreement on the identity of *obesa* Fab. Girschner (3) divided the

species into four varieties—*obesa* Fab. (as *obesa umbripennis* Girschn.), *nervosa* Meig. (as *obesa nebulosa* Girschn.), *nebulosa* Panz. (as *obesa fascipennis* Girschn.) and *violacea* Meig. (as *obesa latipennis* Girschn.). The variation attributed to these so-called varieties corresponds closely to the diversity shown by the three genera *Euphorantha*, *Alophoropsis* and *Alophorella* of this paper.

It is evident also from Townsend's descriptions of *Alophorella* (9) that he had no very definite picture of *obesa* when the genus was erected; in his keys *Alophorella* is described with "male wings normal" while in the text "wings short and broad, normally in the male with anal angle much enlarged and costa bulging on the prestigma." Because of the variation in European determinations of *obesa* and the inconsistencies in Townsend's generic descriptions a somewhat arbitrary stand has been taken in applying the concept of *Alophorella* to *Hyalomyia aeneoventris* and allies which includes the European variety *obesa nebulosa* Panz.

For the purpose of this summary the following limit is placed on the genus:

Length 3-6 mm. Black, the abdomen shining or subshining brownish or purplish at least in the central region; wings narrow or slightly widened, not whitish, clear or stained with brown, the staining not following the veins. Head one-third wider than high; flat front longer than the face; epistoma long and warped forward, the antennal and oral margin axes about equal; parafacials not scooped out, the facialia plus the parafacialia about three-fourths as wide as the distance between the vibrissae; eyes narrowly separated, the frontalia distinct throughout; vertical and ocellar bristles distinct although fine; front with two or three rows of hairs outside the frontal row anteriorly; vibrissae strong, generally distinct and larger than the accessory vibrissae. Thoracic chaetotaxy as in *Euphorantha*. Wings usually not widened, but in some specimens with an arcuate costa and slightly enlarged anal area; colour clear or brown stained; petiole of 5R about one-third the length of the preceding section of R_5; C_1 reaching the margin of the wing. Abdomen oval, shining brownish or purplish in the central region or with very light brownish pollen in this region. Piercer narrow, curved up; sheath narrow, long triangular, about twice as long as the preceding sternite.

In North America two species of *Alophorella* occur. Both of these are highly variable, containing specimens in which the male wings are either wide or narrow, stained or clear.

Male abdomen highly polished purple, at least centrally; squamae white; front silvery grey .... *polita* n. sp.

Male abdomen thinly greyish or brownish pollinose, subshining centrally; squamae generally brownish or with a yellow tinge; front golden, brownish or yellowish-grey .... *aeneoventris* (Williston)

Alophorella polita n. sp.

Male. Length 4-6 mm. Antennae and arista black, the second antennal segment somewhat reddish; frontalia velvety black; front, face, cheeks and occiput greyish pollinose, the front somewhat darker in colour; cheeks and occiput white haired; palpi long, yellow.

Thorax dark, thinly greyish pollinose; mesonotum with four darker vittae, the vittae on the prescutum narrow and separated except in front, very broad and only narrowly separated on the mesoscutum, the central pair short; scutellum subshining; pleural hair black. Wing narrow, the costa slightly arcuate and the anal area somewhat enlarged (fig. 24); colour clear with a brownish stain in the costal cells and extending in a triangular-shaped stain from the tip of R_1 to the posterior cross vein; squamae white. Legs black, the femora with some white hair posteriorly.

Abdomen mostly shining purple, thinly greyish pollinose around the margin and over the apex; abdominal hair semierect, black on the dorsum, yellow on the venter.

Female. Head and thorax coloured as in the male. Wing narrow, wholly clear without brown markings; veins yellow; squamae white. Abdomen black, thinly pollinose over the posterior three segments, the pollen of segments two and three very thin, subshining brownish centrally, greyish laterally; segment four greyish pollinose, the pollen thinner centrally. Otherwise except for sexual differences as in the male.

Holotype. ♂, White Mts., New Mexico, NFk Ruidoso, about 8200 ft. on flower of *Solidago trinervata*, 8.17 (Townsend): in the United States National Museum, Washington.

Allotype. ♀, same data as type.

Paratypes. 5 ♂, 3 ♀, same data as type, 3 ♀, White Mts., New Mexico, 8.20 (Townsend), 1 ♀, White Mts., New Mexico, 8.3 (Townsend), 1 ♂, 1 ♀, Moscow, Idaho (Aldrich), 1 ♂, Lewiston, Idaho (Aldrich), 1 ♀, Minot, N.D., June 18, 1918 (J. M. Aldrich), 1 ♂, Colorado Springs, Colo., July (Townsend), 2 ♂, University of Colorado, Boulder, Colo., Oct. 2, 1917 and Oct. 1, 1919, 1 ♂, Edmonton, Alta., 27.VII.1925 (O. Bryant) in the U.S.N.M., Washington. 1 ♂, 1 ♀, Tahique, New Mexico, 25.VI.41 (E. L. Todd), 1 ♂, 1 ♀, Boulder, Colo., 3.VI.1932 (M. T. James) in Reinhard's collection, College Station, Texas. 1 ♂, Gallatin Co., Mont., July 28, 1913 (H. E. Smith) in the M.C.Z., Cambridge. 1 ♂, Seton Lake, Lillooet, B.C., 4.VI.1926 (J. McDunnough), 1 ♂, Vernon, B.C., Aug. 12, 1917 (M. H. Ruhmann), 1 ♀, Slave Lake, Alta., Aug. 15, 1924 (Bryant), 1 ♂, Mont. Exp. Stat., Bozeman, Montana, July 1, 1916; 1 ♀ Gallatin Co., Montana, Aug. 1, 1917, 1 ♂, Lethbridge, Alta., June 18, 1926 (H. L. Seamans) in the Canadian National Collection, Ottawa.

Alophorella aeneoventris (Williston)

Hyalomyia aeneoventris Williston, Trans. Ent. Soc. Amer., XIII, 286, 1886; type male, Washington (Kansas ?).

Hyalomyia robertsonii Townsend, Proc. Ent. Soc. Wash., II, 136, 1891; type female, Illinois (Kansas); Robertson, Can. Ent., XXXIII, 285, 1901, synonymy.

Phasia brevineura West, Jour. N.Y. Ent. Soc., XXXIII, 123, 1925; type male, Ithaca, New York (Cornell): New Synonymy.

Phasia furva West, Jour. N.Y. Ent. Soc., XXXIII, 123, 1925; type female, Truro, Nova Scotia (Cornell): New Synonymy.

This well known species occurs over most of the continent in two rather poorly characterized geographical subspecies or races.

Alophorella aeneoventris aeneoventris (Williston).

Male. Length 6-7 mm. Antennae and arista black; frontalia black; parafrontals dark grey pollinose, sometimes slightly yellowish; face, cheeks and occiput silvery grey, the cheeks with white hairs; palpi yellow.

Thorax dark, lightly grey pollinose; mesonotum with four darker vittae which are narrower and more widely separated on the prescutum but very wide, confluent or very narrowly separated behind the suture, the central pair short; scutellum brownish, grey at the sides. Wings broadened, the anal area somewhat enlarged and the costa arcuate (fig. 22); colour clear, strongly marked with brown in the costal region and centrally, often with a very distinct central brown band; squamae white, brownish or yellowish in the central region. Legs black, the femora with some white hair posteriorly.

Abdomen subshining brownish, the pollen of the central region very thin, only evident when the specimen is viewed from behind, the lateral margins of segments two and three and the whole of segment four and five with conspicuous grey pollen; abdominal hair wholly black, semierect.

Female. Wings narrow, clear with yellow veins; squamae translucent. Abdomen black, greyish and brownish pollinose, the brownish pollen of the central regions of segments two and three and along the posterior margins of these segments very thin, only evident when the abdomen is viewed from behind; lateral margins of segments two and three and the whole of segment four covered with greyish pollen; otherwise except for sexual differences as in the male.

Distribution. ALBERTA (Evansburg, June 30); BRITISH COLUMBIA (Victoria, Oct. 10; Royal Oak, Sept. 13; Vernon, Sept. 10; Carson, Sept. 15); WASHINGTON (Spanaway, July 2).

Alophorella aeneoventris robertsonii (Townsend)—

This form is the commonest Phasiine in the Eastern part of the continent and probably the most variable.

Male. Length 3-6 mm. Antennae black, the second segment sometimes brownish or reddish apically; frontalia black; front greyish-yellow, brownish or golden pollen; face, cheeks and occiput silvery grey, the cheeks with white hair; palpi yellow.

Thorax as in *aeneoventris aeneoventris*, the greyish pollen somewhat more distinct than in that form. Wings narrow, the anal area not enlarged and the costa straight or very slightly arcuate (fig. 23); colour clear, the wings of the larger specimens stained with dark brown in the costal cells and with a brown streak across the centre, those of the smaller specimens nearly or quite clear, the brown stains obsolete; squamae generally dark brown or yellowish, the lower half of the front scale white. Legs black, the femora with some white hair posteriorly.

Abdomen black, the posterior three segments covered with very thin brownish and greyish pollen which is only evident when the specimen is viewed from behind, the pollen of the central region brownish, subshining, that on the lateral margins and at the apex bluish-grey.

Female. Front silvery-grey to yellowish-grey; legs wholly black haired; wings narrow, entirely clear; veins yellow; squamae white with a yellowish or darker area in the centre; abdomen mostly as in the male but the pollen heavier.

Distribution. ALBERTA (Lethbridge; Slave Lake, Aug. 15; Wabamun, July 2-5); BRITISH COLUMBIA (Trinity Valley, July 25); CALIFORNIA (Carmel, May 21); COLORADO (North Park, July); DISTRICT OF COLUMBIA: IDAHO (Moscow, July 31–Sept. 1); ILLINOIS (Urbana, Sept. 26; Odin, May 28; Pulaski, June 2; Monticello, June 28); INDIANA (LaFayette, May 1–Oct. 27; Shelby, May 24; S. Wanatch, June 1; Attica, Oct. 7); MANITOBA (Teulon, Sept. 22); MARYLAND (College Park, Oct. 30; Beltsville, July 7; Grove Hill, Oct. 30–Nov. 2; Chesapeake Beach, Sept. 9); MASSACHUSETTS (Melrose Hghds., July 7–Oct. 16; Holliston, June 1–July 17; Reading, Sept. 24; Tyngsboro, Sept. 25; Lexington, July; N. Andover, Sept. 25; Agawam, Oct. 10; N. Saugus, July 30; Wellesley, Aug. 15; Chicopee, July 8; Mt. Holyoke Gap, Sept. 17); NEW BRUNSWICK (Fredericton, July 10; McGivney, July 12); NEW HAMPSHIRE (Jackson, Sept. 25; Alstead, Aug. 5; White Mts.; Franconia, Aug. 6; Base Mt. Wash., Aug. 27–Sept. 1; Noxon Camp, July 5; Kinsman Notch, July 7); NEW JERSEY (Riverton, Sept. 20–Oct. 10; Clementon, June 8; Ramsay, May 16); NEW YORK (Ithaca, Aug. 25–Sept. 19; McLean Res., Aug. 24–Sept. 24; Atwater, July 16; Honoeys Falls, July 11–Aug. 18; Wilmington Notch, Aug. 1); NORTH CAROLINA (Black Mts., May); NOVA SCOTIA (Kings County, Aug. 10); ONTARIO (Ottawa, April 8–Oct. 18; Jordan, July 14–Sept. 20; Fitzroy, July 25; Simcoe, May 28–June 29; Gananoque, July 9; Lake Abitibi, July 3-25); PENNSYLVANIA (Clarks Val., June 28); QUEBEC (Aylmer, June 13–Sept. 28; Hull, Sept. 20; Laniel, July 24; Norway Bay, Aug. 25; Montreal, Sept. 8; Abbotsford, June 18–Sept. 6); VERMONT (Rutland, Aug. 1-15; Chittenden, Aug. 1-15); VIRGINIA (Potomac Creek, May 25; Falls Church, May 3–Sept. 20; Glencarlyn, May 20; Louisa, Oct. 16; Great Falls, Oct. 23; Chain Bridge, Oct. 3); WASHINGTON (Spanaway, June 30–July 3); WISCONSIN (Milwaukee, Aug.).

DIVISION V—**Hyalomya** and allies

This entire division plus members of the genus *Paraphasia* (DIVISION II) were placed in the genus *Phorantha* by Coquillett; all but one of the species were placed as synonyms of *occidentis* Wlk. This lumping has caused sad confusion in the subsequent determinations of the various species and in the host records attributed to *occidentis*.

The genus *Phorantha* Rondani (genotype *Conops subcoleoptrata* Linne) and the genus *Hyalomya* R-Desvoidy (genotype *Phasia pusilla* Meigen) in their restricted senses have not been recorded from North America.

Genus **Phoranthella** Townsend

1915—*Phoranthella* Townsend, Pr. Biol. Soc. Wash., XXVIII, 23; one species as *P. morrisoni* Townsend (1915): Townsend, Manual of Myiology VII, 68, 1938.

Length 4-5 mm. Robust, short with clear narrow wings and thinly pollinose abdomen. Head wider than high; nearly flat front longer than the concave face; epistoma long, well warped forward, the oral margin axis slightly longer than the antennal axis; eyes very narrowly separated,

the frontalia pinched out in front of the ocelli (fig. 2); parafacials slightly wider than the facialia, the two together being five-sixths as wide as the distance between the vibrissae; vibrissae strong, but not well differentiated from the accessory vibrissae; frontal bristles extending two or three below the lower point of the frontalia, in one row; vertical bristles absent or hardly differentiated; ocellar bristles weak or absent, somewhat stronger in the female; palpi as long as the antennae, enlarged apically; cheek one-sixth eye height.

Acrostichals 0.1; dorsocentrals 0.1 (1.1); intraalars 0.0; supraalars 0.1; lateral scutellars 2; sternopleurals 1 (rarely 2). Wings narrow, pointed, clear, longer than the abdomen (fig. 26); petiole of 5R half as long as the preceding section of R_5; cubitulus broadly rounded; M_3 midway; squamae very broad. Legs stout, femora enlarged; claws and pulvilli very long in the male; hind tibia short and curved, three-fourths to four-fifths as long as the hind femur; bristles long and stout; hind femora with two or three very stout preapical spines antero-dorsally, these spines about as long as the width of the femur where situated; hind tibia with two or three long, stout anterodorsals and two posterodorsals; mid tibia with a stout anteroventral and a shorter anterodorsal and posterodorsal.

Abdomen short and pointed; abdominal hairs erect, moderately dense; female sternites strongly drawn together and humped, the third sternite obsolete, the sixth sternite very large; sheath broad, curved ventrally; piercer narrow with a hooked tip, curved dorsally.

Phoranthella morrisoni Townsend

? *Hyalomyia punctigera* Townsend, Proc. Ent. Soc. Wash., II, 135, 1891; type male, Dixie Landing, Va. (Kansas ?).

Phoranthella morrisoni Townsend, Proc. Biol. Soc. Wash., XXVIII, 23, 1915; Manual of Myiology VII, 68, 1938; type female, Georgia (U.S.N.M.).

The type of *punctigera* could not be located but the description fits this species better than any other. *P. morrisoni* TT. was erected for a specimen determined by Coquillett as *Phorantha occidentis* (Wlk.) but it remained undescribed until 1938.

Male. Antennae and arista black; frontalia black; front, face, cheeks and occiput silvery grey; cheeks white haired; palpi dark brown or black; two or three accessory vibrissae about as long as the vibrissae present.

Thorax dark; humeri, lateral line and pleura grey pollinose; mesonotum and scutellum shining or subshining black, the mesonotum sometimes faintly grey pollinose in front of the scutellum; pleural hairs black. Wings clear or fumose basally; veins yellow; squamae white, yellowish centrally. Legs wholly black; pulvilli grey.

Abdomen black, greyish pollinose centrally on the first segment, posteriorly on the second and on the whole of segments three, four and five; most of the first segment and a triangular spot on segments two to four dark; abdominal hairs dense, erect, black, each hair set in a shining non-pollinose black spot.

Female. Slightly smaller than the male; a row of five or six stout bristles on the oral margin next to the vibrissae present, each as stout as the vibrissae; mesonotum more distinctly pollinose than in the male with distinct vittae on the prescutum. Wings clear; squamae white; otherwise coloured as in the male.

Distribution. ARIZONA (Palmerlee, May); DISTRICT OF COLUMBIA (Eastern Branch, Oct. 22); IDAHO (Moscow, Sept. 1; Boise); ILLINOIS (DuBois, Aug. 9; Algonquin, Oct. 8; Mason City, June 5); INDIANA (LaFayette, Oct. 19); MARYLAND (Beltsville, May 28; Grove Hill, Nov. 2); MASSACHUSETTS (N. Andover, July 16; Melrose Hghds., July 14; Cohosset, Aug. 19); NEVADA (Ormsby Co., July 6); NEW JERSEY (Malagra, July 2); NEW MEXICO (Las Cruces, Aug. 31); TEXAS (College Station, May–Nov. 12; Austin, Oct. 7; Dallas, April 19, Neuscest, April 25); VIRGINIA (Mt. Vernon, Oct. 30; Potomac Creek, May 23).

Genus **Alophorellopsis** Townsend

1926—*Alophorellopsis* Townsend, Gen. Musc. Hum. Trop. Am. 209; one species as *A. capitata* Townsend (l.c., 284, 1926– Brazil); Manual of Myiology VII, 36, 1938.

The genotype *capitata* differs from the two North American species included in the genus in several respects, chief of which include the broad triangular wings in the female which are broadened as in the males of the other species; a very narrow front, the minimum width being less than the diameter of an ocellus; the presence of a small seta at the base of the third vein; a somewhat different arrangement of the scutellar bristles; the extensively pollinose abdomen.

The following generic description is taken from the two North American species which are tentatively referred here.

Length 2½-6 mm. Narrowed, black; male wings whitish, the anal area enlarged; abdomen generally lightly pollinose with shining spots. Head wider than high, more or less semicircular in profile; the flat front longer than the face; epistoma strongly warped forward; parafacials slightly wider than the facialia, the two together about as wide as the distance between the vibrissae; eyes separated by a distance equal to three-fourths the width of the ocellar triangle, the frontalia obsolete on the posterior half; ocellar and vertical bristles differentiated, often weak; frontal bristles stopping near the anterior points of the frontalia, in one row; vibrissae differentiated in the male but not in the female; palpi short, somewhat enlarged apically.

Acrostichals 0.1; dorsocentrals 1.1; intraalars 0.1; supraalars 1.1; lateral scutellars 2; sternopleurals 1. Wings enlarged in the anal area, the costa straight or arcuate; petiole of 5R nearly half as long as the preceding section of R_5; cubitulus broadly rounded. Legs stout, the hind tibiae of the male somewhat shorter than the hind femora; claws and pulvilli of the male long.

Abdomen short and rounded to elliptical, black, generally lightly pollinose with distinct shining spots; piercer narrow, curved up; sheath closely appressed to the piercer, also curved up.

The two North American species may be separated as follows:

Male wings with strongly arcuate or bulging costa; abdomen wholly pollinose, without conspicuous shining spots..*argentifrons* n. sp.
Male wings with straight costa, enlarged only in the anal area; abdomen shining or with conspicuous spots..................................*purpurascens* (Townsend)

Alophorellopsis argentifrons n. sp.

Male. Length 6 mm. Head wholly bright silvery pollinose; frontalia deep velvety black; arista ringed with brown above the swelling; palpi brown.

Thorax black, thinly greyish pollinose; prescutum with two narrow shining vittae in the acrostichal rows and a broader lateral vitta on each side. Legs shining black. Wings very broad across the base, the anal area enlarged and the costa arcuate (fig. 27); colour whitish, with all the veins except the anal broadly bordered with brown so that the whole anterior half of the wing appears coloured, the centres of the cells somewhat lighter; C_1 not reaching the posterior wing margin; squamae largely white, the lower lobe broadly bordered with brown.

Abdomen subshining brownish purple, broadly pollinose laterally on segments one and two with silvery pollen; segments three and four wholly yellowish-grey pollinose. Abdomen narrow and rather long.

Holotype. ♂, Oliver, B.C., 28.VI.1923 (C. B. Garrett): No. 5592 in the Canadian National Collection, Ottawa.

Alophorellopsis purpurascens (Townsend)

Hyalomyia purpurascens Townsend, Proc. Ent. Soc. Wash., II, 137, 1891; type female, Illinois (U.S.N.M.).

Phorantha calyptrata Coquillett, Rev. Tach., 44, 1897; type male D.C. (U.S.N.M.): NEW SYNONYMY.

Phorantha humeralis Robertson, Can. Ent., XXXIII, 286, 1901; type male, Carlinville, Illinois (Illinois). NEW SYNONYMY.

Male. Length 2.5 mm. Antennae black; front, face, cheeks and occiput silvery-grey; palpi dark brown.

Thorax dark, the mesonotum thinly brownish-grey pollinose; prescutum marked with a broad V or W-shaped marking formed from the coalescing of the central vittae; on the mesonotum the central vittae are very broad and joined, short, the lateral vittae continuous with the lateral vittae of the prescutum; pleural hair black. Wings distinctly whitish except in very small specimens which have nearly clear wings; anal area enlarged, costa straight (fig. 28); colour typically whitish with brown markings along the veins, these markings sometimes nearly as extensive as in *argentifrons*, but usually only the anterior basal region so marked, sometimes the wings practically without brown; squamae wholly deep velvety black or with a central white region. Legs black.

Abdomen mostly shining brownish-green to purplish, thinly greyish pollinose laterally and on the apical segments, each hair with a conspicuous shining spot at the base; at times however, the abdomen is wholly shining black without pollen while at others the black shining spots are reduced; abdominal hair long, erect and black.

Female. Head similar to the male. Thorax black, the mesonotum more distinctly grey pollinose than in the male, the vittae narrower. Wings moderately wide, whitish, without brown markings; squamae white, a little yellowed on the edges. Abdomen black, the posterior three segments and a central spot on segment one covered with shining grey pollen, each hair with a black basal spot which is somewhat smaller than those of the male.

Distribution. DISTRICT OF COLUMBIA (Eastern Branch, Sept. 22); GEORGIA (Peach Co., May 29, ex *Sehirus cinctus* P. deB.); IDAHO (Moscow, July 12–Aug. 21); ILLINOIS (Peoria, May 20, Algonquin, Aug. 16; Mason City; Urbana, June 18; Champaign, July 14; Anna, May 17); INDIANA (LaFayette, June 21–Oct. 23; Logansport, Aug.); MARYLAND (Plummers Is., June 7); MEXICO; MISSISSIPPI (Agr. Coll., May 5; Starkville, June 9); NEW MEXICO (Sororro, Rio Beneto, Las Cruces); NORTH CAROLINA (Raleigh, June 12); ONTARIO (Jordan, July 17; Fitzroy, July 25); QUEBEC (Lanquare, July 21); TENNESSEE (Nashville, Nov. 5); TEXAS (College Station, Sept. 11; Victor, Oct.); VIRGINIA (Falls Church, Sept. 17–Nov. 13); WASHINGTON (Spokane, June).

In this species small specimens tend to have a narrower, clearer wing and less pollinosity on the abdomen than do the larger specimens. In the series examined for this study, very small specimens with narrow, nearly clear wings and shining black abdomen were particularly common in the north west (Washington), medium sized specimens with narrow, whitish wings and slightly pollinose abdomen formed the major constituent of the species in the central states while the large specimens with broad, white and brown wings and more heavily pollinose abdomen were commoner in the East. Both the large and medium sized specimens were found throughout the range but only in the Washington series are there any very small, shining black forms. The intergradation, however, is very complete and no characters could be found that would suggest varieties or subspecies.

Genus **Hyalomyiopsis** n. gen.

Genotype. Hyalomyia aldrichi Townsend, Proc. Ent. Soc. Wash., II, 136, 1891.

Length 2.5-6 mm. Black; wings narrow, hyaline; abdomen thickly covered with grey pollen. Head nearly round when viewed from in front, slightly wider than high; nearly flat frontal profile well sloped, one-half longer than the face; face concave; clypeus somewhat depressed, one and a half times as long as wide, parallel sided; epistoma as wide as the clypeus, half as long as same, well warped forward, the oral margin axis longer than the antennal axis; eye very large, the upper facets larger than the lower; cheek about one-eighth eye height; eye separated by a distance less than the width of the ocellar triangle, the frontalia generally obliterated on the posterior third; ocellar and inner vertical bristles developed in both sexes; frontal bristles stopping at the antennae base, the parafrontals bare outside the frontal row (fig. 1); parafacials one and a half times as wide as the facialia, the two together three-fourths as wide as the distance between the vibrissae; vibrissae short but well differentiated; antennae reaching three-fourths of the way to the vibrissae; arista thickened one-half way; palpi slightly enlarged at the tip.

Thorax narrower than the head; acrostichals 0.1; dorsocentrals 1.1; intraalars 0.1; supraalars 1.1; sternopleurals 1; pteropleural as long as the sternopleural; lateral scutellars 2, the hind decussate. Wings narrow, clear, the costa straight and the anal area not enlarged (fig. 25); petiole of the apical cell nearly half as long as the preceding section of R_5; M_3 midway between R_6 and the broadly rounded cubitulus; M_1 joining R_5 nearly at right angles. Legs robust, the femora enlarged and the hind

femur curved; hind tibia as long as the hind femur; claws and pulvilli elongate in the male. Abdomen oval, pollinose; marginal rows of bristles on segments two, three and four fairly distinct; abdominal hairs sparse, erect; sternites all well formed in both sexes; ventral membrane widely exposed in the male, narrowly so in the female; sixth sternite of female shorter than the fifth; sheath narrow, pointed, closely appressed to the piercer, one-third longer than the sixth sternite; piercer sharp, narrow, pointing slightly upwards, just projecting beyond the sheath.

This genus which finds its closest ally in the European *Hyalomya* is represented in North America by two species both of which are largely Western in distribution. These species may be separated as follows:

Length 2.5-4 mm. Abdominal hairs sparse, arranged in four or five rows on each segment, the hairs with an inconspicuous black basal spot; bristles of tibiae fine.. *aldrichi* (Townsend)

Length 5-6 mm. Abdominal hairs dense, in nine or ten rows on each segment, the hairs with a rather distinct black basal spot; bristles of tibiae very stout.. *robusta* n. sp.

Hyalomyiopsis aldrichi (Townsend)

Hyalomyia aldrichi Townsend, Proc. Ent. Soc. Wash., II, 136, 1891; type male, South Dakota (U.S.N.M.).

Hyalomyia celer Townsend, Trans. Amer. Ent. Soc., XXII, 65, 1895; type female, Las Cruces, New Mexico (Kansas). NEW SYNONYMY.

Phorantha pruinosa Robertson, Can. Ent., XXXIII, 284, 1901; type male, Carlinville, Illinois (Illinois): NEW SYNONYMY.

Phasia cara West, Jour. N.Y. Ent. Soc., XXXIII, 123, 1925; type male, Karner, New York (Cornell): NEW SYNONYMY.

This species is probably the best known member of the complex and is the form most commonly determined as *Hyalomya occidentis* Wlk. It is our smallest Phasiine.

Male. Length 2.5-4 mm. Antennae and arista black, the third antennal segment with greyish pollen; frontalia black; front, face, cheeks and occiput silvery grey, the occiput darker above; palpi dark brown.

Thorax black, the mesonotum subshining; humeri, disc of mesonotum and pleura very thinly greyish pollinose; pleural hairs black. Wings clear; veins brown or yellow; squamae white. Legs dark; tibial bristles short and weak.

Abdomen black; first segment except for a narrow posterior region, a small median spot on the anterior edge of segments two, three and four without pollen, the rest of the abdomen densely silvery-grey pollinose; abdominal hairs sparse, the hairs in three to five rows on each segment.

Female. Similar to the male; the thoracic pollen is more evident than in the male and the mesonotum shows four very faint vittae; abdomen coloured as in the male, the pollen grey or greyish-yellow, each hair with an evident shining spot at the base.

Distribution. ALASKA (Skagway, June 3); ALBERTA (Medicine Hat, Oct.; High River, Banff, Oct. 2; Lethbridge, May 22; Waterton, July 13; Morrin, June 4; Orion, Aug. 13; Kannanaskis, June 23); ARIZONA (Teme, June 19; Palmerlee); CALIFORNIA (Niles, May 9; Pacific Grove, May 10; Los Gatos, Feb. 16; Pasadena, April; Pleasanton, June 24; Redlands;

Tracy, Oct. 30); Colorado (Boulder, Sept. 30; Grant, Aug. 20; Denver, Sept. 3; Greeley, Aug. 31; Ft. Collins; Canon City); District of Columbia (Eastern Branch, Oct. 22); Idaho (Moscow, July 15–Sept. 5; Kinghill, Sept. 29; Yale; Carey, Sept. 23; Juliaetta, June 5); Illinois (Mason City, June 5); Indiana (LaFayette, May 24–Oct. 22; Evansville, May 7; Michigan City); Kansas (Garden City, Oct. 24); Manitoba (Treesbank, July 13–Oct. 2; Aweme, Oct. 6; Teulon, July 7); Massachusetts (Melrose Hghds., June 19); Mexico; Montana (Bozeman, Sept. 2); Nebraska (West Pt., Sept. 6-9; Partley, July 15; Indienola, July 5); New Jersey (Atco; Woodbury, June 1–July 31; Bueno Vista, Nov. 6; Clementon, Oct. 6); New Mexico (Socorro); New York (Karner, Nov. 4); North Dakota (Bismarck, June 14; Lisbon; Minot, June 18); Ontario (Ottawa, May 15; Norway Point, July 15); Saskatchewan (Swift Current, May 30; Saskatoon, May 23; Cypress Hills, June 5; Indian Head, July 7); South Dakota (Rapid City; Custer; Brookings; Pierre, May 22); Texas (College Station, July 11); Utah (Logan Canon, June 6; Moab, Aug. 20); Washington (Spokane, July 7; Fishtrap Lake, Aug. 8; Pullman); Wisconsin (Milwaukee, July 29).

Hyalomyiopsis robusta n. sp.

Male. Length 5-6 mm. Head coloured as in *aldrichi*. Thorax black, the mesonotum subshining; humeri, posthumeral area and disc of mesonotum with evident grey pollen, the prescutum showing four very faint vittae. Wings clear; veins yellow; squamae white. Legs dark; tibiae bristled with long stout bristles. Abdomen black; the first segment (except a narrow central area posteriorly) and a narrow median spot on the anterior margins of segments two, three and four without pollen, the rest of the abdomen shining greyish pollinose; abdominal hairs comparatively dense, in nine or ten rows on each segment.

Female. Similar to the male except that the abdominal pollen is greyish or greyish-yellow and each hair has a black shining spot at the base.

Holotype. ♂, Summit Prairie, Grant Co., Ore., El. 5500 ft., VIII.7.41 (M. & R. E. Rider); in H. J. Reinhard's Collection, College Station, Texas.

Allotype. ♀, same data as type.

Paratypes. 2 ♂, 1 ♀, same data as type; 2 ♂, Lump Gulch near Gilpin, Colo., VIII.8.34 (N. Dondelinger and H. G. Rodeck); 1 ♂, Colorado, 25.VIII.31; 1 ♂, Boulder, Colo., VI.21.32 (M. T. James); 1 ♂, 1 ♀, Boulder, Colo., VI.5.32 (M. T. James); 1 ♂, Logan, Utah, VI.8.31, in Reinhard's Collection. 1 ♀, Clark Co., Kansas, June, 1962 ft. (F. H. Snow) in the Kansas University Collection. 1 ♂, Moscow, Idaho, IX.4.08 (J. M. Aldrich); 2 ♀, Moscow, Idaho, IX.5.08, on goldenrod, and VIII.26.12 (Aldrich); 1 ♀, Salt Lake, Utah, Oct. 20, 1913 (L. P. Rockwood); 1 ♂, San Diego Co., California; 1 ♂, Berkeley, Alameda Co., Calif., July 27, 1910 (J. C. Bridwell); 1 ♀, (Ft. Collins, Colo., 5.18.94 (J. H. Cowen), in the United States National Museum, Washington. 1 ♂, Ft. Collins, Colo., 7.30.15 (C. F. Baker) in the Museum of Comparative Zoology, Cambridge. Also one specimen from Ft. McLeod, British Columbia, Aug.

NORTH AMERICAN SPECIES NOT INCLUDED

Hyalomya occidentis Walker—Insecta Saundersiana, part IV, 260, 1856.

Mas: Atra, caput argentatum; abdomen canum basi vittaque fasciisque duabus nigris; alae limpidae

> Deep black; head with a silvery covering; frontalia deep black, triangular; abdomen hoary, black towards the base and with a black stripe and two black bands; legs black; wings colourless; veins black, yellow towards the base and along the fore border; alulae white; poiser yellow. Length of body $2\frac{1}{2}$ lines (about 5 mm.); of the wings 5 lines. United States.

The description is closest to the Californian species *Paraphasia nigra* n. sp., described in this paper. Certain discrepancies as the "frontalia triangular," "wings colourless," and "alulae white" and the smaller dimensions make it advisable to leave the species as unidentifiable for the present.

Alophora luctuosa Bigot—Annales Soc. Ent. France, Dec. 1888, 255.

A. luctuosa, ♂, ♀, – Long. $4\frac{1}{2}$ mill – Undique nigro parum nitente; calyptris albido-flavido tinctis, halteribus fulvis; alis hyalinus base, anguste, pallido fulvo pictus – ♀, Simillima; fronte late fusco-nigro vittata– Amerique du Nord; montagnes Rocheuses, specim. 3 ♂, 1 ♀.

Coquillett recorded this species as a synonym of *occidentis* but the description indicates rather one of the *Alophorella* group.

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AN APPRAISAL OF SPRAY MATERIALS FOR THE CONTROL OF APPLE SCAB IN ONTARIO[1]

G. C. Chamberlain[2]

Dominion Laboratory of Plant Pathology, St. Catharines, Ontario

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For many years lime sulphur has been the standard fungicide for the control of apple scab. Its effectiveness as a preventive, eradicative, and adhesive spray has been demonstrated repeatedly. A serious limitation to its usefulness, however, is its tendency to induce foliage injuries detrimental to growth and yield. The extent of injury may vary in different localities and be influenced greatly by such factors as vigour of tree, method of spraying, dosage, and seasonal conditions. This danger of foliage injury has served to discredit lime sulphur for orchard spraying and has directed attention to the milder elemental or wettable sulphurs as possible substitutes. The present report concerns the results of spray trials with certain of these materials as well as with modifications of the Ontario spray calendar for apples.

MATERIALS AND METHODS

The experiments, commenced in 1939, were conducted at St. Catharines in the laboratory orchard comprising ninety-eight 11-year-old MacIntosh trees planted 28 feet × 28 feet on a diagonal plan. The orchard has been subject to severe outbreaks of scab, and control proved difficult in seasons favourable for the development of the disease. Sprays were applied according to the development of buds, foliage, and fruit at the delayed dormant, pre-pink, calyx, and two cover sprays, as outlined in the Ontario spray calendar. Bordeaux $7\frac{1}{2}$-15-100 was used for the delayed dormant spray, the differential spraying commencing with the pre-pink application. Arsenate of lead at recommended strength was added to all sprays. The following fungicides were used:

(1) *Commercial Lime Sulphur*, at the strength of $2\frac{1}{2}$ gal. to 100 gal. of water with $7\frac{1}{2}$ lb. hydrated lime, was used for the pre-bloom applications and at 2 to 100 for the calyx and 1st cover spray. For the 2nd cover application, Bordeau $2\frac{1}{2}$-5-100 was employed. In 1943 and 1944, the strength of lime sulphur was $1\frac{2}{3}$ gal. to 100 (1-60).

(2) *Camden Flotation Sulphur Paste* (35% Sulphur). Flotation sulphurs are the most finely divided of all elemental sulphurs. Camden paste was used at the rate of 20 lb. to 100 gal. of water for the pre-bloom and calyx sprays and $12\frac{1}{2}$ to 100 for the two cover sprays, with and without half strength lime sulphur in pre-bloom and calyx sprays. In 1944, the amount of flotation sulphur paste was 16 to 100 and 10 to 100 for the late sprays.

(3) *Koppers Dry Flotation Sulphur* (95% Sulphur). This flotation sulphur was used in 1943 at $7\frac{1}{2}$ lb. to 100 gal. of water for the calyx spray and at 6 lb. for the 1st and 2nd cover.

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[1] Contribution No. 816 from the Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.

[2] Associate Plant Pathologist.

(4) *Micro Flotox* (95% Sulphur). This is a sulphur prepared by the Micronizer process of grinding sulphur which results in a very finely divided product, next in fineness to that of the flotation sulphurs. It was used at the rate of 7 lb. to 100 gal. of water for the pre-bloom and calyx sprays and at 5 lb. for the cover applications.

(5) *Sulfuron* (97% Sulphur). This product, one of the group of elemental sulphurs of larger particle size than the foregoing, was used at the same rate as Micro Flotox.

(6) *Bartlett's Wettable Sulphur* (Micron sized 94% Sulphur). This product, reputed to approximate closely the fineness of micronized sulphur, was used at the same rate as Micro Flotox.

(7) *Kolofog Bentonite Sulphur* (30% Sulphur). This product, which consists of sulphur fused with bentonite, was used at the rate recommended by the manufacturers, 7½ lb. to 100 gal. of water, with and without weak lime sulphur for the pre-bloom and calyx applications.

(8) *Fermate.* This organic fungicide, containing 70% ferric dimethyl-dithiocarbamate as the active ingredient, was used at the rate of 2 lb. with an equal quantity of hydrated lime to 100 gal. of water.

(9) *Coposil* (20% copper). This so-called fixed copper was used in the 1st and 2nd cover sprays where summer oil emulsion was employed in the latter and 3rd cover spray for codling moth control. It was used at the rate of 2½ lb. to 100 gal. with 5 lb. hydrated lime added.

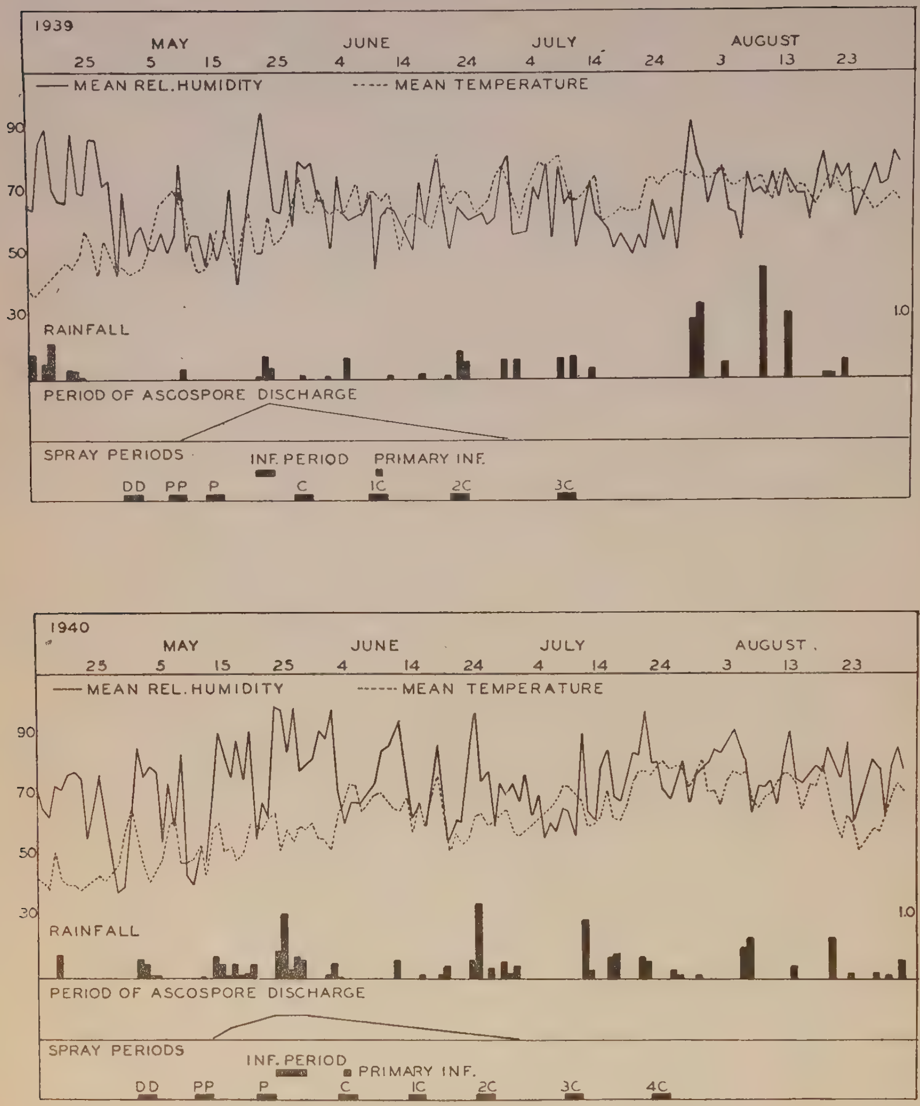
Orthex, a mineral oil type of spreader-adhesive, was added to certain sprays in 1943 and 1944 at the rate of 1 pint to 100 gal. of spray mixture.

Orvus (sodium lauryl sulphate) spreader, 1 pint to 100 gal., was added to certain sprays in 1943.

SEASONAL DEVELOPMENT OF SCAB

Meteorological data and information relative to the development of the apple scab fungus, host, and disease are shown graphically in Figures 1 to 3. The date of maturation of ascospores was ascertained by microscopical examination of overwintered scabby MacIntosh leaves, and the times and intensity of ascospore discharge were recorded by means of spore traps. Ascospore discharge, which occurs during rain, was found to extend from the latter part of April to the end of June; the period of major discharges occurred when the trees were either approaching or in full bloom. The distribution, amount, and duration of rainfall at this time were the important factors in determining the incidence of scab and the effectiveness of the sprays.

In 1939 and 1941, scab was of very minor importance. Both years were notable for a lack of rainfall in the early growing season, followed by comparatively dry summer weather. Only light scattered showers of short duration occurred during the period when the majority of ascospores were discharged, and consequently there was an absence of any serious infection. In 1939, very little scab was present in the orchard until August, when wet weather favoured the development of late infection on the fruit. In 1941, practically no scab occurred in the sprayed plots and only 3% of the fruit from unsprayed trees was infected.



Explanation of Plates

Figure 1. Graphic summary of certain meteorological and seasonal data relating to apple scab in the Niagara Peninsula in 1939 and 1940.

In the remaining years, scab was very prevalent, no crop being harvested from unsprayed trees. Rainfall in May was excessive, with frequent showers followed by protracted periods of high humidity, especially at the peak of ascospore discharge. In 1940 and 1943, the critical infection periods occurred prior to bloom and were followed by the early establishment of the disease. This factor and inclement weather made control of scab very difficult. In 1942, the rainfall in May was even greater than in

1940 and 1943, but the infection periods were of shorter duration and occurred later in relation to host development. In 1944, little infection followed the more active ascospore discharges previous to bloom. However, the disease developed freely during the extremely damp weather of the late bloom period and spread rapidly with the recurring wet weather in June. Because of the prevalence of scab, it was deemed advisable to make an extra application of fungicides to all plots at the time of the 3rd cover spray (July 3).

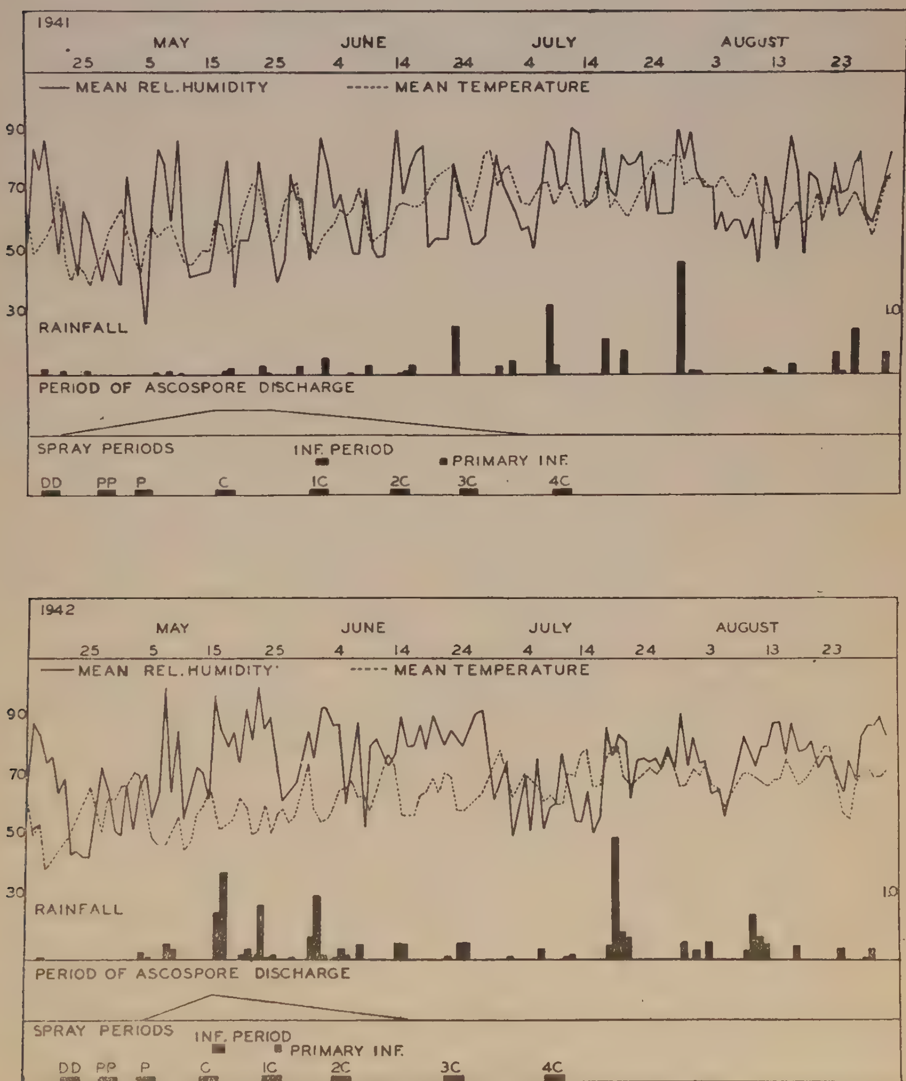
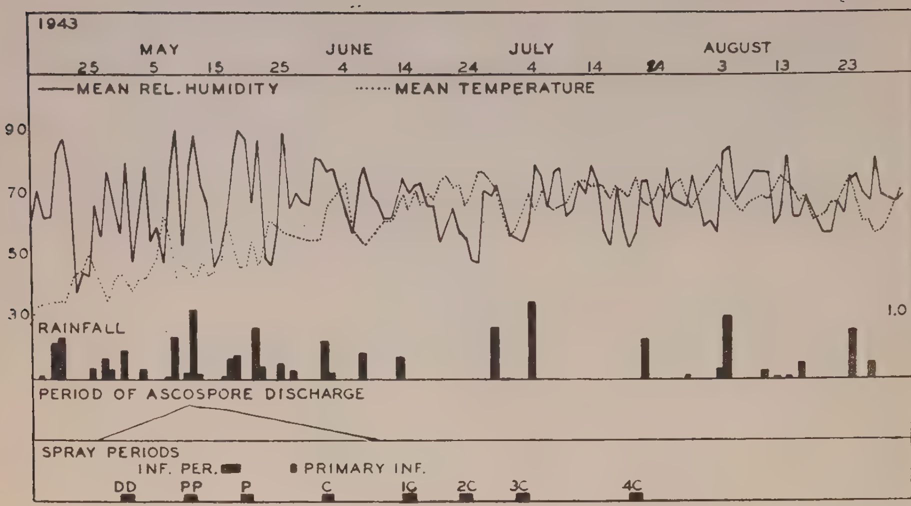


FIGURE 2. Graphic summary of certain meteorological and seasonal data relating to apple scab in the Niagara Peninsula in 1941 and 1942.



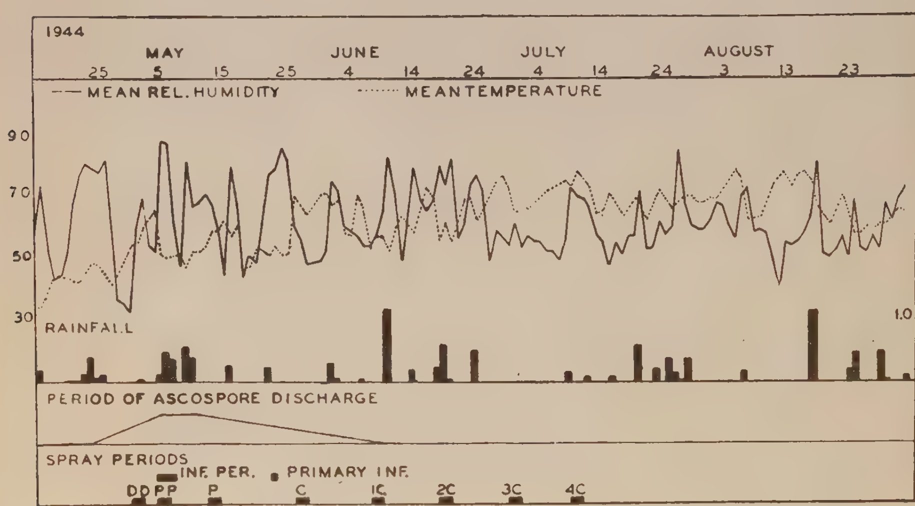


FIGURE 3. Graphic summary of certain meteorological and seasonal data relating to apple scab in the Niagara Peninsula in 1943 and 1944.

RESULTS OF THE EXPERIMENTS

In the spray trials of 1939-42, the same program was carried out annually, and the data obtained by examining the total crop harvested from each plot are summarized in Table 1.

TABLE 1.—RESULTS OF SPRAYING EXPERIMENTS AT ST. CATHARINES, 1939-1942

Spray treatment	MacIntosh apples with scab infection			
	1939	1940	1941	1942
	%	%	%	%
1. No sprays	51.3	94.8	3.6	94.1
2. Lime sulphur	4.7	10.9	T	2.9
3. Kolofog	24.0	71.7	T	12.3
4. Kolofog + lime sulphur 1-80	25.8	38.0	T	9.6
5. Flotation sulphur paste	11.6	28.6	0.0	7.2
6. Flotation sulphur paste + lime sulphur 1-80	8.6	13.5	0.0	5.6
7. Lime sulphur; Coposil: oil	3.0	5.6	0.0	1.5
8. Kolofog; Coposil: oil	7.4	11.6	T	3.0
9. Kolofog + lime sul. 1-80; cop.: oil	4.4	3.3	T	1.3
10. Flotation sulphur paste; cop.: oil	4.5	10.6	T	5.6

Lime sulphur 1-40 was the most effective in controlling scab, but it caused considerable foliage injury, especially in the wet seasons. The injury included dwarfing, distortion, marginal scorch, and tip-burn of leaves. In addition, lime sulphur increased the amount of yellow leaf and defoliation due to arsenical injury. Lime sulphur injury is important because it reduces the area and impairs the efficiency of the leaves. A number of investigators have studied its effect on growth and yield of trees. Burrell (1) reported a reduction of one-third in yield of trees sprayed with lime sulphur, as compared with wettable sulphur, and Rasmussen (4), a reduction of almost one-half. In this experiment, a lack of uniformity both in the size of the tree and in soil conditions rendered the crop and growth records unsatisfactory, and no direct evidence was obtained that the injury had a detrimental effect on tree performance. However, the deleterious effect of lime sulphur was clearly evident in thinner foliage, and smaller, distorted, and paler leaves.

The wettable sulphurs eliminated the danger of foliage injury but were less effective and less reliable than lime sulphur. Their fungicidal efficiency was influenced greatly by seasonal conditions, a fact clearly shown by the results obtained in 1940 and 1942. In 1940, when moisture conditions during the pre-bloom period were particularly favourable for scab, they proved of limited value. They gave much more satisfactory control in 1942, a season in which infection periods were of short duration and scab development was late in relation to host development (late bloom). The addition of $\frac{1}{2}$ strength lime sulphur to the wettable sulphurs for the pre-bloom and calyx sprays improved control of scab in 1940, but was of little value under the conditions existing in 1942. This combination spray, while not entirely eliminating lime sulphur injury, is considered warranted in seasons particularly favourable for the early development of scab.

Flotation sulphur paste was preferable to bentonite sulphur, especially under the severe conditions of 1940. The better performance of flotation sulphur emphasizes both the importance of high sulphur content in the spray and of fineness of sulphur particles in controlling scab. Flotation

sulphur paste was found much less convenient to use than the dry sulphur and required extra time and care to assure its proper dispersion in the spray tank.

Excellent control of scab was obtained where the various sulphurs were replaced with Coposil and Coposil in a 1% summer oil emulsion in the 1st and 2nd cover sprays. This treatment, in addition to its main purpose of reducing codling moth injury, has considerable merit in preventing late season infection of the fruit. However, the fruit had a somewhat inferior colour and finish in comparison with that of the other plots.

Table 2.—Results of spraying experiments at St. Catharines, 1943

Spray treatments	Scab on harvested MacIntosh apples				
	No apples	Total scab*	Light	Medium	Severe
		%	%	%	%
1. No sprays	No harvest	100.0	—	—	—
2. Lime sulphur 1-60	4469	31.7	15.9	6.9	9.0
3. Koppers dry flotation sulphur	4080	36.0	28.9	4.4	2.7
4. Sulfuron	3851	68.5	41.7	14.6	12.2
5. Kolofog	3510	83.5	26.4	24.9	32.2
6. Koppers dry flot. s. + Orthex	1423	14.3	12.2	1.2	0.9
7. Koppers dry flot. s. + Orvus	3365	30.7	25.7	3.0	2.0
8. Sulfuron + Orthex	2941	33.6	27.7	3.9	2.0
9. Sulfuron + Orvus	4138	48.6	37.5	6.8	4.3
10. Koppers dry flot. s.; Coposil: oil	2771	24.3	19.2	4.2	0.9
11. Sulfuron; Coposil: oil	2575	34.3	22.1	7.2	5.0
12. Fermate + lime	732	30.2	29.0	0.8	0.4

* Scab infection was classified into three categories as follows:
Slight – a single infection up to ⅛ inch diameter or several pin-point lesions aggregating this amount.
Medium – one or more lesions aggregating more than ⅛ inch and up to ⅜ inch diameter.
Severe – numerous infections exceeding an aggregate of ⅜ inch diameter or where fruit showed cracking or malformation due to scab.

The season of 1943 was favourable to the early and serious development of scab, and effective control was extremely difficult to attain.

Although, as indicated in Table 2, no treatment gave satisfactory commercial control, the results of the 1943 tests provide further evidence of the greater effectiveness of the finely divided sulphurs, represented by Koppers dry flotation sulphur. With this material, not only only was there a smaller percentage of scabbed fruit but the fruit was less severely affected than that to which Sulfuron was applied at the same strength. Both Sulfuron and Kolofog were ineffective under the conditions prevailing in that year. With them, a high percentage of the fruit became seriously infected. These results further substantiate the previous conclusion that these types of wettable sulphurs are of limited value in seasons favourable to the early development of scab.

Much improved control of scab resulted from the addition of Orthex, a mineral oil spreader-adhesive, to the wettable sulphurs used for the calyx and cover sprays. This material, which appeared to improve coverage and to increase sulphur deposit on foliage and fruit, was superior to Orvus,

which added little to the control of scab, except when used with Sulfuron. Orvus was observed to foam considerably when agitated at high speed and did not show any special merit.

Lime sulphur, used at a weaker strength (1-60), caused moderate foliage injury and failed to show any advantage over dry flotation sulphur in controlling scab. A much higher percentage of the infected fruit from trees sprayed with the former was graded as culls than from trees sprayed with the latter.

The use of Coposil in place of the sulphurs in the cover sprays improved scab control, thus confirming previous results. However, a new development was the occurrence of a moderate to severe foliage spotting. Similar injury, attributed to the oil, was observed in other orchards. No explanation can be offered as to why this injury occurred.

The new organic fungicide Fermate proved very promising. In this plot, infection was relatively unimportant.

Another serious outbreak of scab was experienced in 1944, the infection developing very freely in the post-bloom period. An extra application of fungicides was made on all plots at the time of the 3rd cover spray and proved of the utmost importance in preventing the spread of the disease to the fruit.

Table 3.—Results of the spraying experiments at St. Catharines, 1944

Spray treatment	Scab on harvested MacIntosh apples				
	No apples	Total scab	Light	Medium	Severe
		%	%	%	%
1. No sprays	No harvest	100.0	—	—	—
2. Lime sulphur 1-60	2526	10.1	7.9	1.5	0.7
3. Flotation sulphur paste	2897	9.6	8.5	0.8	0.3
4. Micro Flotox	2209	10.5	9.6	0.5	0.4
5. Bartlett's wettable sulphur	3422	30.8	21.9	4.3	4.6
6. Kolofog	1082	26.2	16.5	5.8	3.9
7. Micro Flotox + Orthex	2556	7.5	6.5	0.7	0.3
8. Bartlett's wett. s. + Orthex	2243	20.5	16.3	2.1	2.1
9. Sulfuron + Orthex	1973	21.9	18.3	2.5	1.1
10. Fermate	2187	3.2	3.1	T	T
11. Kolofog lime sulphur 1-80	1954	10.9	9.6	0.9	0.4

The results in 1944 (Table 3) support those of previous years. In the plots sprayed with wettable sulphurs alone, the best control was obtained with those having the finest particles, namely, flotation sulphur paste and Micro Flotox. Orthex was of little value when used with micronized sulphur, but definitely improved the control obtained with the other materials. In this connection it should be pointed out that Orthex was added only in the pre-bloom and calyx applications. Since the latter and the subsequent cover sprays proved the more important in controlling scab, it might reasonably be assumed that even better results would have been obtained if Orthex had been added to the later cover sprays.

Fermate, with lime and Orthex, excelled all other treatments. The trees and fruit were outstandingly free from scab; but the trees showed more red mite injury and there was a greater infestation of the insect on the fruit at harvest than on the sulphur sprayed trees.

Lime sulphur 1-60 and the combination spray of bentonite sulphur plus lime sulphur 1-80 gave good control of scab, but in both cases considerable yellow leaf and defoliation developed after the calyx application. The defoliation was quite marked and a moderate scald of the fruit occurred. It was evident that the combination spray had little advantage over lime sulphur in respect to host injury.

SUMMARY AND CONCLUSIONS

These spray experiments demonstrate conclusively that lime sulphur 1-40 or 1-60 strength is the most effective fungicide for controlling scab, but cannot be considered "safe" under Niagara Peninsula conditions. Its use as an eradicant rather than a protectant spray might be warranted under conditions of severe outbreaks of scab or where such outbreaks are to be feared more than the occurrence of foliage injury. If lime sulphur is used, the strength recommended is that of 1-60, and when in combination with wettable sulphurs, 1-80, for the pre-bloom and calyx applications. For the post-bloom applications a wettable sulphur alone is preferred.

The milder elemental or wettable sulphurs possess the merit of "safety." They appear to have limited value in seasons favourable for early prebloom infection. They must be considered as protectant sprays, and when extremely wet conditions prevail in the early season, proper timing and adequate coverage are of the utmost importance in securing satisfactory results. Furthermore, experience suggests that, during prolonged wet periods, extra applications may be necessary.

Flotation sulphur, in dry or paste form, and micronized sulphur proved the most effective and most reliable substitutes for lime sulphur. Supporting evidence of the value of micronized sulphur was obtained in eight commercial orchards under observation outside the Niagara Peninsula, where it was used in 1944 and gave control of scab equal to that obtained with lime sulphur 1-60 or wettable sulphur plus lime sulphur 1-80.

Wettable sulphurs tend to adhere rather poorly. In this connection, the benefit of adding spreader-adhesive materials to the wettable sulphurs was demonstrated clearly in 1943. The addition of Orthex caused a flocculation of the spray suspension, and gave increased spray deposit as well as improved coverage and adhesiveness. This increased protection is particularly valuable under wet conditions at the time of the pre-bloom and calyx sprays, when the trees are most susceptible to infection.

Results were conclusive with respect to the special modification of the Ontario spray calendar recommended for orchards heavily infested with codling moth. This schedule, which employs copper in place of sulphur for the first and second cover sprays, was very effective in preventing fruit infection. However, from the standpoint of the colour and finish of the fruit, it was inferior to the regular sulphur schedules.

The results obtained with the new synthetic organic fungicide Fermate are of special interest. This fungicide has been under experimental observation in New York, Ohio, Virginia, British Columbia, and elsewhere for several seasons and has given results in the control of scab equal to or better than that obtained by the most effective of the wettable sulphurs. Tests in Virginia (6) have shown that it is compatible with summer oils, and thus it offers promise in the schedule for the control of codling moth. Recently other organic fungicides have been developed which in preliminary trials have shown great promise for the future. Some of these materials are reported (3, 5) to exhibit great specificity for certain diseases and to have therapeutic value, and their use is reputed to result in better sizing and colouring of the fruit. At the present time, they are not available for commercial use and no recommendation concerning them can be made.

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SOME STUDIES ON *MACROPHOMINA PHASEOLI* (MAUBL.) ASHBY IN ONTARIO[1]

A. A. Hildebrand, J. J. Miller and L. W. Koch[2]

Dominion Laboratory of Plant Pathology, Harrow, Ontario

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During the course of a plant disease survey in Essex County in southwestern Ontario in August, 1944, a diseased soybean plant was found that exhibited symptoms strongly suggestive of Charcoal Rot. When minute sclerotia embedded in necrotic cortical tissue near the base of the stem of the affected plant were transferred to culture media, pure cultures of an organism subsequently found to be *Macrophomina Phaseoli* (Maubl.) Ashby were readily obtained. Prior to that time the presence of this pathogen on soybeans in Canada had not been known. Indeed, the only report of what may have been the same fungus on *any* host in Canada, is a brief notation in 1934 (3) citing the occurrence of *Sclerotium bataticola* Taub., on diseased fruits of pepper in Lincoln County, south, central Ontario. Hoffmaster and Tullis (6) have recently recorded that, in the United States, Macrophomina dry rot or charcoal rot, has been reported from 27 states, being found mostly throughout the southern half of the country, but it does occur as far north as Illinois and Indiana and has been recorded from Douglas County, Oregon. It is interesting to note that Douglas County, Oregon, and Lincoln and Essex Counties in Ontario, the three locations that, to date, mark the most northerly points in North America from which the pathogen has been reported, all lie just north of the 42nd parallel of latitude.

Concurrently with the isolation of *M. Phaseoli* from soybean, a second isolate that appeared to be almost identical with the first was obtained from a diseased specimen of cotton that had been sent to the Harrow laboratory from Texas[3]. Not only on cotton but on many other hosts of outstanding importance, including corn and soybeans, charcoal rot is creating a problem of major pathological and economic significance in the United States. The two last-mentioned crops, corn and soybeans, are among those grown most extensively in Essex County. The presence of the pathogen having been established here, it seemed advisable to gain some further information not only about the fungus itself but also about its potential pathogenic capabilities especially as related to the two crop plants mentioned above.

DESCRIPTION OF THE DISEASE

Attention was first attracted to the soybean plant on which the disease was found by the fact that it had been prematurely killed and thus stood out conspicuously among the surrounding healthy plants. In removing the plant from the soil a strip of epidermis had been torn off the stem just above the crown thus exposing the light-coloured, necrotic, sub-epidermal tissue. Scattered thickly over the latter and appearing as small black specks were the sclerotia of the fungus (Figure 1). Sclerotia were not

[1] Contribution number 820, Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.
[2] Assistant Plant Pathologist, Agricultural Assistant and Pathologist-in-Charge, respectively.
[3] Through the courtesy of G. E. Altstatt, College Station, Texas.

observed externally on the epidermis of the affected area of the stem. Another fungus disease commonly occurring on soybeans in Ontario, known as pod and stem blight, also very often attacks the plant towards the basal region of the stem. In the case of this latter disease, however, the minute, black, dot-like pycnidia of the causal organism, *Diaporthe Sojae* Lehm., are usually readily visible *on the surface* of affected areas and tend to be arranged in rows.

ISOLATIONS FROM DISEASED PLANTS

(*a*) *From Soybean*

On August 22, 1944, 64 individual sclerotia were transferred from freshly-exposed cortical tissues of the diseased field specimen to 16 plates of potato dextrose agar prepared according to the method of Riker and Riker (12). The agar in 8 of the plates had been acidified to the extent of two drops of 5% lactic acid per 15 ml. of medium while that in the remaining plates was left non-acidified. Four sclerotia were transferred to each plate.

In less than 17 hours, the sclerotia had germinated to the extent of approximately 100% and long filaments of mycelium were already permeating the medium. After 25 hours colonies averaging over one-half inch in diameter surrounded many of the sclerotia. A microscopic examination at 41 hours revealed that new sclerotia were developing profusely on all plates and at 65 hours myriads of these were visible to the unaided eye.

Since the above first attempt many additional sclerotia transferred to culture media from the original diseased specimen have never failed to germinate at ordinary room temperature and provide cultures that in turn developed sclerotia in abundance.

(*b*) *From Cotton*

In the course of making isolations from specimens of diseased cotton plants presumably affected with cotton wilt and from which it was expected to obtain cultures of *Fusarium vasinfectum* Atk., for use in certain comparative studies of Fusarium, there developed colonies of a sclerotium-producing fungus that closely resembled the one recently obtained from soybean. Because of their apparent similarity it was decided to use both in pathogenicity tests that were being planned. For convenience the isolates obtained from soybean and from cotton will be referred to as the Ontario and Texas strains, respectively.

INFECTION EXPERIMENTS

Series 1.—*Experiments in which stems of soybean plants were injured artificially and inoculated with the Ontario strain.*

On September 1, 1944, flap-type wounds were cut with a sharp scalpel in the cortical tissues at the base of the stem of healthy, 57-day-old soybean plants, variety A. K. Harrow, growing in pots in the greenhouse. Agar bearing mycelium and sclerotia of 8-day-old, mono-sclerotial cultures of the Ontario strain was inserted in the wounds which were then covered with moist absorbent cotton bound in place with adhesive tape. Check plants were treated in an exactly similar manner except that sterile agar was inserted in the wound. The number of plants involved, together with other relevant data and the results obtained are shown in Table 1.

TABLE 1.—RESULTS OF INFECTION EXPERIMENT INVOLVING ARTIFICIAL INJURY AND INOCULATION OF STEMS OF SOYBEAN PLANTS WITH ONTARIO STRAIN OF *M. Phaseoli*, SEPT. 1, 1944

Pot		Condition of stems			Final results			
					Checks		Inoculated plants	
No.	Plants	Nov. 7, 1944	Dec. 14, 1944	Mar. 13, 1945	MP +*	MP −**	MP +	MP −
1	Checks Nos. 1-3	All alive, healthy	All alive, healthy	All dead		3		
	Inoculated Nos. 1-3	1, 2 alive, healthy	1, 2 dead—M.P. + S.†				2	
		3 dead						1
2	Inoculated Nos. 4-9	All alive, healthy	4 dead—M.P. + S.				1	
			5-9 alive, healthy	5-9 dead—M.P. + S. + P.‡			5	
3	Inoculated Nos. 10-15	10-13 alive, healthy	10-13 dead—M.P. + S.				4	
		14-15 dead—M.P. + S.					2	
4	Checks Nos. 4-9	All alive, healthy	4 alive, healthy	4 dead		1		
			5-9 dead			5		
5	Inoculated Nos. 16-18	16, 17 alive, healthy	16-17 dead—M.P. + S.				2	
		18 dead—M.P. + S.					1	
				TOTALS		9	17	1

* MP + = *M. Phaseoli* present.
† MP + S = *M. Phaseoli* with sclerotia.
** MP − = *M. Phaseoli* absent.
‡ MP + S + P = *M. Phaseoli* with sclerotia and pycnidia.

If reference is made to Table 1 it may be noted that of 18 inoculated plants, 17 became infected whereas none of the 9 check plants showed any evidence of the disease. At 67 days after inoculation, only 4 of the inoculated plants had become infected. At 105 days after inoculation, an additional 9 inoculated plants had become infected. All plants examined at these two points showed only sclerotia of the fungus. On March 13, 1945, about 6½ months after inoculation, the last 4 inoculated plants had become infected and were showing *pycnidia of the fungus as well as sclerotia* scattered over the infected areas.

From the evidence it was clear that the plants had not become susceptible until they were approaching or had reached a condition of senescence. It was strongly suggested that the Ontario strain had acted as a facultative parasite. Once infection had taken place, its spread was rapid and in some cases sclerotia were visible on areas of the stems up to 9 inches in extent.

Series 2.—*Experiments in which seeds of corn and soybean were sown in soil artificially infested with the Ontario and Texas strains respectively.*

This series of tests was carried out in 3 Wisconsin tanks of 8-container capacity each, operated at 21°, 27° and 33° C., respectively. Containers and soil, the latter a mixture of 2 parts greenhouse compost and 1 part medium lake-shore sand, were sterilized with chloropicrin. The soil in 4 of the containers of each tank was infested with the Ontario strain of the organism, that in 2 others with the Texas strain, while that in the two remaining containers served as checks. Soil infestation was accomplished by addition of cornmeal-sand medium upon which the organism had been grown for 10 days, to the top 4 inches of soil in the containers, in the proportion of about 1½% by volume. The technique followed very closely that recently used with success by Miller (9). Non-disinfected seed of soybean variety A. K. Harrow and of corn inbred Hy, 15 seeds respectively per container, were used in the tests. Non-disinfected seed was used in order that results obtained might be compared with those of Semeniuk (13) who, in testing the susceptibility of corn inbred Hy to attack by *Sclerotium bataticola* Taub., used non-disinfected seed and also because in Series 1 the organism had exhibited such weak and delayed parasitic capability that it was felt the application of a fungicide to the seed might inhibit infection altogether.

Counts were taken daily of seedlings as they emerged. In Table 2, where final totals are recorded, it can be seen that differences in emergence are small and cannot be regarded as significant. As had been noted by Semeniuk (13) in his studies, no pre-emergent rotting of seed occurred in the infested soils. In the case of corn, maximum emergence took place on the 6th, 4th and 3rd days after planting, at 21°, 27° and 33° C., respectively.

TABLE 2.—PERCENTAGE EMERGENCE OF CORN AND SOYBEAN SEEDLINGS GROWN AT DIFFERENT TEMPERATURES IN INFESTED AND NON-INFESTED SOIL

Soil temperature ° C.	Emergence of seedlings					
	Ontario strain		Texas strain		Check	
	Corn	Soybean	Corn	Soybean	Corn	Soybean
	%	%	%	%	%	%
21	100	86.6	100	100	100	86.6
27	100	96.6	100	86.6	100	93.3
33	100	100.0	100	100	100	93.3

Maximum emergence of soybean seedlings took place on the 5th day after planting at 21° and on the 3rd day at both 27° and 33° C.

(*a*) *Corn*

About the ninth day after planting, some of the corn seedlings in both inoculated and check soils at 33° showed a dying of the tips of the lower leaves, a general flaccidity, a necrotic condition of the stem just at the ground level and a badly rotted primary root system. Examination of and isolations from affected plants revealed the presence of *Fusarium moniliforme* Sheldon. Within 3 weeks, more heavily infected seedlings died, the number varying from 3 to 7 in the different containers at 33°. Seedlings apparently less heavily infected survived and together with those that seemed to have escaped infection developed into vigorous plants. Later, the same sequence, was observed in the 27° and 21° tanks but in less accentuated form and with lower mortality of seedlings.

Although the intrusion of *F. moniliforme* had defeated the primary purpose of the experiment i.e., an evaluation of the parasitic capability of the two Macrophomina strains, nevertheless, a representative number of the corn seedlings grown at the different temperatures was removed from the check and inoculated soils and examined microscopically. Mycelium and sclerotia of both strains were found as follows:

(*a*) sparingly in necrotic tips of a few secondary roots at 33°.
(*b*) frequently in decaying pericarp and mesocotyl tissues at 27° and 33°.
(*c*) consistently and abundantly in coleoptile tissue (Figure 2) at all temperatures.

In most cases *F. moniliforme* was also present in the tissues examined, but from coleoptiles especially, both Macrophomina strains were readily re-isolated in pure culture. Even when coleoptiles were badly rotted and showed an abundance of sclerotia no evidence of spread of infection to underlying stalk tissues could be found. The evidence suggested that both strains should be regarded as facultative parasites, apparently being able to attack certain tissues of the corn plant only in their later stages of senescence. Such parasitic capability as they did exhibit was more readily apparent at 33° than at the lower temperatures. The isolate of *S. bataticola* used by Semeniuk (13) was perhaps a more aggressive parasite than those employed in the present studies. He reports that: "In most of the seedlings in the infested soil, necrosis was severe in mesocotyl and primary

root" and that, "Sclerotia were observed extending along the seminal roots as much as 8 cm. from the seed. The development of necrosis began at the seed and progressed for varying distances along one or all members of the primary root system and along the mesocotyl. Secondary roots became infected following complete necrosis of the mesocotyl during the early development of the seedling." In the present studies it was *F. moniliforme* that caused damage comparable to the above. Undoubtedly the seed used in the present studies carried in or on it a much greater amount of *F. moniliforme* or a much more aggressive and virulent strain of the pathogen than that used by Semeniuk. The latter investigator intimated that, "The activity of *S. bataticola* apparently was influenced considerably by the antibiotic activities of other soil organisms." Perhaps in the present studies *F. moniliforme* was present in such quantity as to greatly modify the parasitic capability of the two strains of *M. Phaseoli* under test.

(*b*) *Soybean*

Two weeks after the seeds were sown examination was begun of the soybean seedlings as they were removed from the check and inoculated soils, and whenever there was any evidence of a diseased or abnormal condition isolations were made and razor sections stained with acid fuchsin in lacto-phenol were prepared for microscopic examination.

No evidence of disease was found in *roots* of plants grown at 21° or 27° in either check or inoculated soil. After 3 weeks roots of plants grown at 33° developed in general a more or less distinct brownish discoloration and frequently root tips tended to become necrotic. Neither by isolation from nor by microscopic examination of selected material could the discoloration or necrosis be correlated with the presence of any particular organism and it was decided that they were evidence of reaction on the part of the plants to a soil temperature considerably in excess of that conducive to optimum growth.

On the underground portion of the *stems* of plants grown for 3 weeks at 27° and 33°, and for 5 weeks at 21°, in the soils inoculated with the two strains of Macrophomina, grayish areas varying both as to number and size, and contrasting more or less distinctly with the surrounding healthy tissue, became visible. Prepared sections of epidermal and sub-epidermal tissues showed the presence of Macrophomina. Incipient infections showed mycelium only or mycelium with sclerotia in earlier stages of development (Figures 6 and 7) while in older infections mycelium had for the most part disappeared leaving only mature sclerotia (Figure 5).

After surface sterilization of stems by immersing them for 30 seconds in a solution of ethyl alcohol and mercuric chloride (1 part 95% C_2H_5OH in 4 parts 1 : 1000 $HgCl_2$) and rinsing in sterile water, tissue plantings from grayish areas were made to acidified and non-acidified P.D.A. Apparently, such treatment was too drastic because nothing developed from the plantings. Thereafter, planting were made to the culture medium following only thorough washing of selected portions of stems under running tap water using a camel's hair brush to facilitate removal of extraneous material. As a check, plantings were made also from presumably healthy tissue in close proximity to the affected areas. The results of the tissue transfers from the stems of 27 plants grown at the 3 different temperatures are summarized in Table 3.

TABLE 3.—SUMMARY OF RESULTS OF ISOLATIONS FROM INFECTED AND HEALTHY AREAS ON UNDERGROUND PORTIONS OF STEMS OF SOYBEAN PLANTS GROWN IN SOILS ARTIFICIALLY INFESTED WITH THE ONTARIO AND TEXAS STRAINS OF *M. Phaseoli*, RESPECTIVELY

Condition of stem	Number tissue plantings made	Plantings remaining sterile		Relative occurrence of organisms							
		No.	%	Alternaria	Macrophomina	Unidentified fungi	Bacteria	Fusarium	Mucor	Penicillium	Trichoderma
				%	%	%	%	%	%	%	%
Infected	90	—	—	28.8	73.3*	2.2	—	—	20.0	35.5	4.4
Healthy	70	22	31.4	32.5	19.8*	3.6	10.5	17.3	14.5	7.9	2.3

* Total for the two strains.

It may be noted from Table 3 that Macrophomina was isolated from infected areas on stems in much higher proportion than from apparently healthy adjacent tissue (73.3% as compared with 19.8%). At the time the isolations were being made it was noted that the representatives of the other genera of fungi recorded in Table 3 were obtained more frequently from larger, more distinct lesions that showed brownish-coloured necrotic tissue. All lesions, including the latter, remained relatively superficial. No stems were girdled and none of the plants with affected stems ever showed symptoms of disease on their above-ground parts. The grayish discoloured areas from which both strains of Macrophomina were consistently isolated often occurred within the zone of root proliferation. It was thought that fissures in the stem caused by the emergence of new roots might provide a convenient infection court. This possibility was carefully investigated but no confirmatory evidence was obtained. The two strains of the fungus appeared equally capable of producing the type of primary infection described above.

In the case of check plants grown in the uninoculated soil at 21° and 27°, the underground portion of the stems remained perfectly healthy. With the check plants grown at 33°, however, the underground portion of some stems showed indistinct, brownish-discoloured areas, from which Alternaria and Penicillium were sometimes isolated.

The above results indicate that in so far at least as one variety of soybeans is concerned, the two strains exhibit some slight degree of primary parasitic capability. They are aggressive enough to infect the epidermal and sub-epidermal tissues of the underground portion of the stem but possess sufficient virulence to cause only localized, superficial injury.

Series 3.—*Experiments in which stems of corn and soybean plants were injured artificially and inoculated with the Ontario and Texas strains respectively.*

In Series 2, a number of corn seedlings had died, as described above, following early attack by *F. moniliforme*. A considerable number also of both corn and soybean plants had been removed from the various containers in the 3 tanks for examination as to infection by *M. Phaseoli*. There still remained an appreciable number of each growing in the soils at the three different temperatures and it was decided to utilize them in a third series of stem inoculation studies. Consequently, using all available plants, the technique employed in Series 1 was repeated, the wounds being made as close to the soil level as possible. An 8-day-old plate culture of the Ontario strain obtained directly from the original field specimen served as a source of inoculum for the corn and soybean plants growing in the soil that in Series 2 had been inoculated with the same organism. Sixteen- and 21-day-old cultures of the Texas strain were used to inoculate the plants growing in the soil that had been already infested with that strain in Series 2. The inoculations were made January 13-15, 1945, when the plants were about 55 days old and they were left undisturbed until March 6. On the latter date all plants were removed from the containers and examined. The numbers of plants involved, their disposition and the results obtained are summarized in Table 4.

TABLE 4.—RESULTS OF INFECTION EXPERIMENTS INVOLVING ARTIFICIAL INJURY AND INOCULATION OF STEMS OF CORN AND SOYBEAN PLANTS WITH ONTARIO AND TEXAS STRAINS OF *M. Phaseoli*

Soil temperature ° C.	Corn				Soybeans				Totals	
	Number and condition of				Number and condition of					
	Inoculated plants	Check plants	Inoculated plants	Check plants	Inoculated plants	Check plants	Inoculated plants	Check plants	Inoculated plants	Check plants
	Ontario strain		Texas strain		Ontario strain		Texas strain			
33	3*/4**	0/3	0/6	0/4	4/12	1/7	0/6	0/4	7/28	1/18
27	3/7	0/4	1/8	0/5	3/13	1/8	0/7	0/4	7/35	1/21
21	1/7	0/5	0/9	0/5	0/15	1/8	0/8	0/5	1/39	1/23
Totals	7/18	0/12	1/23	0/14	7/40	3/23	0/21	0/13	15/102	3/62

* "Numerator" in each case denotes number of plants infected with *M. Phaseoli.*
** "Denominator" in each case denotes number of injured check and inoculated plants.

If reference is made to Table 4 it will be noted that altogether only 18 plants, 8 corn and 10 soybeans, became infected with *M. Phaseoli.* Since 16 of the 18 infected plants were growing in the warmer soils at 27° and 33°, and since the inoculations had been made at a point low enough on the stems to be within the zone of influence of heat radiated from the soil, it would seem that temperature might have been a factor influencing infection. It may be further noted that with a single exception all of the plants that became infected had been inoculated with the Ontario strain of the organism. This would suggest difference in specificity on the part of the two strains. From column 7 of the table, it will be seen that 3 of the check plants became infected. These were among plants grown in containers the soil of which had been inoculated with the Ontario strain in Series 2, so that infection likely took place from the soil.

Occurrence of sclerotia on the stems as revealed by examination with the dissecting microscope was the basis for determining infection of plants. If more critical methods had been adopted such as those employed by Weimer (14) the number of infected plants might have been found to be greater. Weimer noted that whereas some plants of Chamaecrista grown in soil infested with *M. Phaseoli* died in earlier stages of their development, others survived and showed little or no evidence of infection. When, however, such plants were disinfected and segments numbered from the root upwards were planted on agar plates, the fungus was recovered from many plants, sometimes from segments taken as high as 3 inches above the ground. Thus, it is possible that more than 15 (= 14.7%) of the 102 injured and inoculated corn and soybean plants—more especially, perhaps, those inoculated with the Ontario strain—may have been infected internally and that such infection might have become apparent if the plants could have been left to come to full maturity.

MORPHOLOGICAL AND CULTURAL CHARACTERISTICS OF THE ONTARIO AND TEXAS STRAINS

In the present invesigation no attempt was made to study the two strains in complete detail. There were noted, however, certain morphological and cultural characters of each on which an accurate though limited, description and comparison may be based.

Mycelium

Comparison of the two strains on a basis of their mycelial characteristics was not attempted. In plate cultures on potato dextrose agar it was observed that the Texas strain differed from the Ontario strain in the presence of narrow-pyramidal tufts of flocculent aerial mycelium, grayish in colour near the surface of the medium and becoming lighter to almost white towards the apex of the tufts.

Pycnidia

Neither strain has produced pycnidia in culture or on the stalks of corn, tomato and soybean plants sterilized with steam. Apparently to date only in two instances both recorded by Haigh (4, 5) have pycnidia of *M. Phaseoli* been obtained in culture.

As mentioned earlier in the present paper, pycnidia did appear, however, on the stems of 4 soybean plants grown in the greenhouse, about 6½ months after they had been injured and inoculated with the Ontario strain of the fungus. When these plants were being examined under the dissecting microscope, it was noted that, scattered here and there among the more readily-recognizable sclerotia, were slightly larger black bodies that in contrast to the sclerotia appeared to be exerting pressure on and breaking through the epidermal tissues. These more conspicuous bodies were found to be pycnidia possessing an inconspicuous truncate ostiole and a membranous to subcarbonaceous wall. Globose to depressed globose in shape, they were found to vary from 100 to 200μ.

Conidia

(a) Shape and Size

The conidia are borne on simple, rod-shaped conidiophores up to 15μ in length, that arise from the entire inner surface of mature pycnidia. From Figure 3 it may be seen that the hyaline, non-septate, thin-walled conidia are variable in shape, oval or elliptical. Prominent in the granular contents of most of them are oil globules, one to several per spore. Two hundred spores in a suspension from 5 different pycnidia were measured and were found to range in length from 12.6 to 28μ, in width from 8.4 to 10.5μ, with a mean of 21.0 $\times$ 9.3μ for these two dimensions, respectively. Eighty-eight per cent of them were found to be between 18.9 and 25.2μ long while 85% were between 8.4 and 9.8μ wide. Ashby (1) comments that "The variations in spore size on the same host may be considerable, Shaw giving as a maximum range on jute in India, 16-29$\times$6-11μ and Sawada for the same host in Formosa, 16-32 $\times$ 7-10μ; the dimensions fall mostly between 16-29 $\times$ 6-9μ."

(b) Germinating Capacity

Spores suspended in tap water or flooded on standard potato dextrose agar germinate in from 1½ to 2 hours at ordinary laboratory temperature

(Figure 4). Well-formed sclerotia were visible within 46 hours in colonies of mono-conidial origin growing in plate cultures on potato dextrose agar. Later when these sclerotia had reached maturity they were found to be indistinguishable from those produced in cultures originating from sclerotia taken directly from the host. Thus the genetical connection between the conidial and sclerotial stages of the fungus was definitely established by the pure-culture method.

In connection with the above it may be mentioned here that from 1924 when Wolf and Lehman (16) intimated briefly that "work is in progress on a root disease (of soybeans) with which *Sclerotium bataticola* is associated" until 1943, there are comparatively few references in North American literature to the incidence of charcoal rot on *soybeans*. During 1943 and 1944, however, many reports of the occurrence of the disease on this host in the United States have appeared. Of some 30 more recent reports consulted by the writers only in four of them (2, 8, 10, 11) is any mention made of the pycnidial stage, and in these the connection between the pycnidial and the sclerotial stage is apparently assumed on the basis of proximity of association of the two. Prior to the present studies the definite connection between the two stages of the organism occurring on soybeans does not seem to have been established by cultural methods.

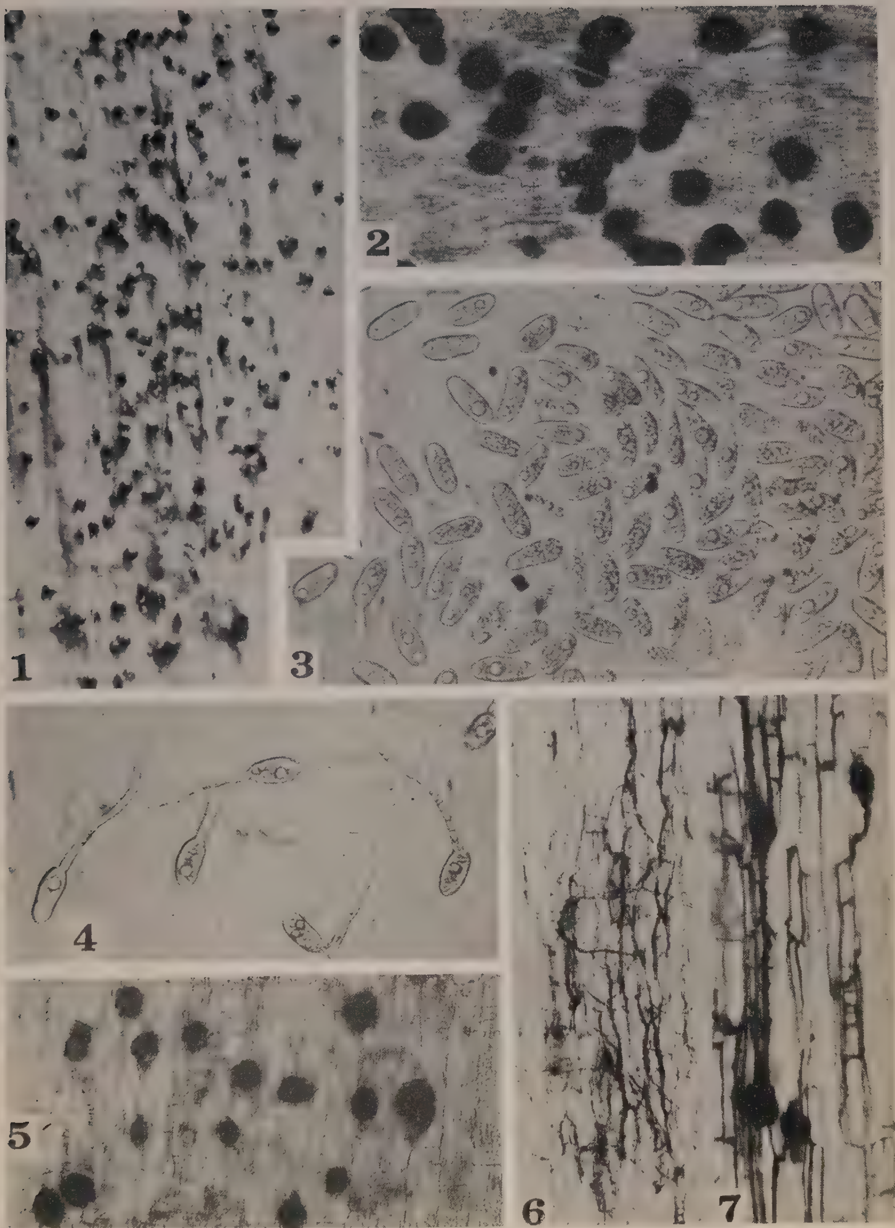
Sclerotia

(a) Shape and Size

The sclerotia of the two strains, small black, shiny bodies are indistinguishable microscopically. Their shape is modified slightly by the substratum in or on which they develop. In agar cultures or on the surface of stems they tend to be globular, oval or pear-shaped. In the cortical tissues of the soybean plant in which the Ontario strain was first noted most of the sclerotia were slightly flattened. In determining size of sclerotia it was found necessary to record their diameters on a two-dimensional basis. Over 1000 sclerotia of the two strains from both natural and artificial substrata were measured. Data in connection with these measurements are summarized in Table 5.

TABLE 5.—SIZE OF SCLEROTIA OF ONTARIO AND TEXAS STRAINS ON BOTH NATURAL AND ARTIFICIAL SUBSTRATA

Strain	Substratum	Sclerotia	
		No. measured	Average size
			Microns
Ontario	Sub-epidermal tissue of original field specimen of soybean	155	89.6 × 74.8
Ontario	Peripheral zone of 25-day-old mono-sclerotial P.D.A. plate culture.	147	99.7 × 89.7
Ontario	Central zone of 25-day-old mono-sclerotial P.D.A. plate culture.	153	100.8 × 89.7
Ontario	Random selections from 25-day-old mono-conidial P.D.A. plate culture.	150	99.4 × 88.9
Ontario	Stem of inoculated, greenhouse-grown soybean plant.	155	91.3 × 76.8
Texas	Peripheral zone of 25-day-old mono-sclerotial P.D.A. plate culture.	143	84.8 × 72.2
Texas	Central zone of 25-day-old mono-sclerotial P.D.A. plate culture.	150	86.1 × 73.8



Mycelium, pycnospores and sclerotia of *M. Phaseoli*. FIGURE 1. Sclerotia of Ontario strain in cortical tissues of naturally-infected field specimen of soybean (X12). FIGURE 2. Sclerotia of Ontario strain in coleoptile of corn (X70). FIGURE 3. Pycnospores of Ontario strain (X400). FIGURE 4. Germinating pycnospores of Ontario strain after 2 hours in tap water (X400). FIGURE 5. Sclerotia of Texas strain in subepidermal tissues of stem of soybean (X70). FIGURES 6 and 7. Incipient infection by Ontario strain in stem of soybean showing mycelium and sclerotia in early stage of development (X70).

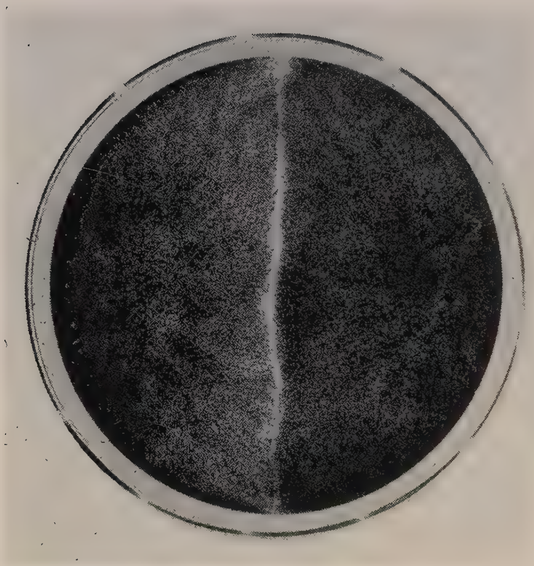


FIGURE 8. Twenty-six-day-old cultures of Ontario (left) and Texas (right) strains of *M. Phaseoli* on potato dextrose agar.

If reference is made to Table 5 it may be noted that the sclerotia of the Ontario strain on the original field specimen of soybean and on the stems of inoculated plants in the greenhouse measured $89.6 \times 74.8\mu$ and $91.3 \times 76.8\mu$, respectively, with an average size of $90.4 \times 75.8\mu$. On P.D.A. plate cultures, sclerotia of the same strain whether of mono-sclerotial or mono-conidial origin, averaged $99.9 \times 89.4\mu$. Thus, the Ontario strain produced larger sclerotia on the artificial medium than on the natural substratum. On P.D.A. plate cultures, sclerotia of the Texas strain averaged $85.4 \times 73.0\mu$. Thus, they are appreciably smaller than those of the Ontario strain on the same substratum. Not only are they smaller but they occur in greater numbers per unit area or volume of medium. The effect of this greater density of smaller sclerotia is that the Texas strain appears much darker in colour than the Ontario strain. As is clearly shown in Figure 8, this may be of diagnostic significance.

(b) Germinating Capacity

On frequent occasions from August, 1944, until April, 1945, sclerotia from the original Macrophomina-infected field specimen have been transferred to plates of both acidified and non-acidified P.D.A. Over this 8-month period the sclerotia have never failed to germinate quickly and to the extent of practically 100%. In making the transfers it was noted that small bits of plant tissue often adhered to a sclerotium. Thus, it would not seem impossible that in an appreciable number of cases the organism might originate not from the sclerotium but from the adhering plant tissue. To investigate this possibility, 25 minute particles of freshly exposed sub-epidermal tissue in close proximity to sclerotia were transferred to plates of acidified P.D.A. from the infected field specimen. In not a single instance was there any development of fungal growth.

In a second test, 25 sclerotia were transferred to acidified P.D.A. from host material after it had been immersed for 30 seconds in an alcohol-mercuric chloride solution (1 part 95% C_2H_5OH to 4 parts 1 : 1000 $HgCl_2$) and rinsed in sterile water. Within 24 hours over 90% of the sclerotia had germinated. In a third test the period of immersion was increased to 60 seconds and in this case only 3 of a total of 25 sclerotia germinated. The results of the above three tests indicate that capacity for germination is inherent in the sclerotia themselves.

Sclerotia of both strains grown on artificial media have shown weak and erratic capacity for germination as compared with those taken directly from the field specimen. Furthermore, there seems to be correlated with increasing age in culture a decreasing capacity for germination on the part of sclerotia of both strains. These statements are based on evidence obtained as follows. Fifty sclerotia of the Ontario strain obtained directly from the infected field specimens and 50 sclerotia of each of the two strains taken from 11-, 21-, and 31-day-old P.D.A. cultures, were transferred to plates of P.D.A. (25 sclerotia per plate) and incubated at 27° C. The plates were examined at definite intervals and germination counts taken, with results as shown in Table 6.

An examination of Table 6 reveals the following points: (a) all the sclerotia taken directly from the field specimen germinated within 18 hours; (b) whatever the source, no sclerotia germinated after 42 hours;

TABLE 6.—COMPARISON OF GERMINATING CAPACITY OF SCLEROTIA FROM THE HOST AND FROM ARTIFICIAL CULTURES OF DIFFERENT AGE

Test	Strain	Source of sclerotia	Number of sclerotia examined	Germination of sclerotia					
				Periodic increments					Total
				18*	26	42	66	90	
				%	%	%	%	%	
	Ontario	Soybean, field specimen	50	100	—	—	—	—	10
1	Ontario	11-day P.D.A. culture	50	38	14	6	0	0	58
	Texas	11-day P.D.A. culture	50	34	8	2	0	0	44
	Ontario	Soybean, field specimen	50	100	—	—	—	—	100
2	Ontario	21-day P.D.A. culture	50	24	10	6	0	0	40
	Texas	21-day P.D.A. culture	50	18	6	9	0	0	33
	Ontario	Soybean, field specimen	50	100	—	—	—	—	100
3	Ontario	31-day P.D.A. culture	50	16	8	6	0	0	30
	Texas	31-day P.D.A. culture	50	0	0	0	0	0	0

* Hours after transfer.

(c) sclerotia of the Ontario strain exhibited a consistently higher capacity for germination than those of the Texas strain; (d) increasing age of culture had a depressing effect on the germinating capacity of both strains, the effect being more marked, however, in the case of the Texas strain.

IDENTIFICATION OF THE ONTARIO AND TEXAS STRAINS

Ontario Strain

On a basis of the morphological characters of its pycnidia, conidia and sclerotia, on both natural and artificial substrata, the Ontario strain can be definitely identified as *Macrophomina Phaseoli* (Maubl.) Ashby.

Texas Strain

Although the pycnidial stage of this strain was not observed, nevertheless. measurements of sclerotial diameter in culture were all, in their means, under the minimum of 120μ permitted for inclusion in Haigh's (5) group C, indicating their similarity in respect of size to the fungi recorded from many widespread areas as *Macrophomina Phaseoli*.

The designation of the isolates from soybean and from cotton as *strains* of *M. Phaseoli*, throughout the present paper, is justified, if not on a basis of their specific host preferences, then on the differences in their morphological and cultural characters to which attention has been directed.

DISCUSSION

In 1931, after reviewing the literature relating to the parasitism of *M. Phaseoli*, West and Stuckey (15) stated that, "As the evidence stands, there is not sufficient proof in any direction. Thus Small and Reichert have obtained positive infection experiments. Hansford and Weir report negative results. The American workers on the other hand describe inoculations indicating weak parasitism." Following their own compre-

hensive studies of the parasitism of *M. Phaseoli* on cotton and jute, the above-mentioned workers concluded that under normal conditions the fungus is not a parasite but that under very moist conditions it will attack jute seedlings. They found further that cotton plants growing in soil deficient in humus may become susceptible to *M. Phaseoli* during a definite period and that under controlled conditions young cotton plants are susceptible to the organism for a certain period of time after artificial defoliation. They found that with defoliated cotton plants, there is a certain correlation between susceptibility and the presence or absence of starch in the tissues. They were led finally to conclude that *M. Phaseoli* is a facultative parasite, such parasitic capability as the organism does display being bound up with the physiology of the host, the host and its environment being implied.

In general, the findings and conclusions of the present writers tend to be more closely in accord with those of West and Stuckey than with those of several other investigators. In the first series of tests in which stems of soybean plants growing in the greenhouse were artificially injured and then inoculated with the isolate of *M. Phaseoli* obtained from soybean, infection appeared and spread rapidly only after the plants had reached the later stages of senescence. Here, infection seemed correlated primarily with physiological changes within the host rather than with any particular factor of the environment. In the second series of tests in which corn and soybeans were grown in sterilized soil artificially infested with isolates of *M. Phaseoli* obtained from soybeans and from cotton, respectively, under controlled conditions at temperatures considered optimum and above and below optimum for these plants, the impression was strengthened in so far at least as corn was concerned that such parasitic capability as the two isolates did display was of the facultative type, their attack on certain tissues (pericarp, mesocotyl, coleoptile) being associated with the senescence or near senescence of these tissues. In attacking the underground portion of the stems of soybean plants and producing superficial, grayish-coloured areas of infection, the two strains displayed definite, though limited, capability as primary parasites. Since infection appeared two weeks earlier on the stems of plants grown at 27° and 33° than on those grown at 21° C., temperature was undoubtedly one of the factors interacting with others in the host-pathogen-environment complex. The correlation between temperature and infection was more clearly indicated in Series 3 where, of a total of 18 plants (8 corn and 10 soybeans) that became infected, 16 (= 88.8%) were growing in the warmer soils at 27° and 33° C. Referring in this connection to work done elsewhere, it may be pointed out that in 1933 Kendrick (7) reported that in California epiphytotics of a destructive stem blight of seedling beans caused by *M. Phaseoli* in its sclerotial stage coincided with the emergence of seedlings during or immediately following periods of 10 days or more with a mean air temperature of 80° F. or above and a daily maximum of about 100°. In connection with inoculation tests involving bean seedlings grown in pots of sterilized inoculated soil Kendrick states, "The results show that *Rhizoctonia bataticola* may cause a destructive blight of seedling beans and thus corroborate the theory suggested by the field observations, i.e., that high temperatures are necessary for infection."

In the present studies it was found that sclerotia of the isolate from soybean produced in culture showed weak and erratic capacity for germination as compared with those taken directly from the infected field specimen. Moreover, sclerotia of both strains showed an apparent loss of viability that increased with age in culture. Sclerotia from a 31-day-old culture of the cotton isolate showed complete loss of viability. In the papers consulted by the present authors no reference has been found to this phenomenon of loss of viability of sclerotia of *M. Phaseoli* in culture. To date no attempt has been made to determine its cause. Its detection suggests that only young cultures should be used as source of inoculum in pathogenicity tests. In a series of 10 experiments Haigh (5) injured and inoculated the stems of 495 plants representing several different genera and species, with isolates of *M. Phaseoli* obtained from sources as widely separated as Ceylon and the United States. In the first 8 experiments, of 359 plants involved only 43 (= 11.9%) became infected. In the last two experiments, 136 plants were injured and inoculated and 97 (= 71.3%) became infected. In the last two experiments Haigh used as inoculum mycelium of 2- and 3-day old cultures. Unfortunately he gives no indication of the age of the inoculum employed in the first 8 experiments. If he had happened to use older cultures that might be one reason why such a relatively small number of plants became infected. It should be pointed out that in the two sets of experiments as indicated above, there was "overlapping" not only of the same host plants but also of the isolates of the fungus used as inoculum. Haigh comments, "The fungus *Macrophomina Phaseoli* has been shown to be extremely plastic in culture. It may be that a similar plasticity in its pathological reaction will account for the inconsistency of experimental results obtained by the present writer and others." Could "plasticity" in the pathological action of the fungus in some cases be accounted for by the use of inoculum that, differing in age, differed correspondingly in the viability of sclerotia of which in part at least it must have been composed?

Semeniuk (13) found that "the activity of *S. bataticola* apparently was influenced considerably by the antibiotic activities of other soil organisms" and Weimer (14) drew attention to the fact that "the pathogenicity of the fungus on the same host is quite variable in different localities."

From the foregoing it may be adjudged that a study of the pathogenicity of *M. Phaseoli* on a particular host could and probably would involve consideration of a number of entirely different yet closely interrelated factors. The present studies have indicated that if, for example, the host were soybeans then such factors as age not only of plants to be inoculated but also of the inoculum to be used and soil temperature would have to receive especial consideration.

SUMMARY

Two isolates of *Macrophomina Phaseoli*, one (the Ontario strain) obtained locally from a field specimen of soybean exhibiting typical symptoms of charcoal rot, the other (the Texas strain) from a diseased cotton plant from Texas, have been compared morphologically and tested as to their pathogenicity on soybean (variety A. K. Harrow) and corn (inbred line Hy).

When stems of soybean plants growing under ordinary conditions in the greenhouse were artificially injured and inoculated with the Ontario strain, the latter acted as a facultative parasite, showing ability to infect the plants only as they approached senescence. Pycnidia as well as the more-commonly-occurring sclerotia were produced on a few plants.

When corn and soybeans were grown at controlled temperatures of 21°, 27° and 33° C., in sterilized soil inoculated with the respective strains, such parasitic capability as both strains displayed was, in the case of corn, of the facultative type. In attacking the underground portion of the stems of soybeans and producing thereon characteristic, grayish-coloured areas of infection, the two strains displayed definite, though limited, capability as primary parasites. Infection appeared earlier on plants grown at the two higher temperatures.

When under controlled conditions similar to the above, the stems of corn and soybean plants were injured and inoculated at the soil level with the two strains, of a total of 102 inoculated plants 15 (8 corn, 7 soybeans) became infected. Fourteen of the latter were among those grown at 27° and 33°, thus reaffirming a correlation between temperature and infection. Since 14 of the 15 affected plants had been inoculated with the Ontario strain, there was a suggestion of host specificity on the part of the latter. Parasitism in all cases was of the facultative type.

In culture neither strain produced pycnidia but these did appear on certain of the greenhouse-grown soybean plants inoculated with the Ontario strain. Pycnidia and conidia are described. Cultures of mono-conidial origin produced the sclerotial stage. Thus, by the pure culture method was established for the first time the genetical connection between the two stages of *the organism occurring on soybean* and on the basis of the morphology of its pycnidia, conidia and sclerotia it was definitely identified as *M. Phaseoli*.

The two strains have been differentiated on the basis of difference in size and number of sclerotia produced in culture. Sclerotia of both strains showed an apparent loss of viability that increased with age in culture. In marked contrast, sclerotia from the original soybean herbarium specimen showed no loss of viability after 8 months.

The parasitism of *M. Phaseoli* in relation to certain biotic and abiotic factors has been discussed.

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A SEED DISPENSER—DEVICE FOR MEASURING SEED BY VOLUME FOR ROD ROW PLOTS[1]

C. H. Goulden[2]

Dominion Laboratory of Cereal Breeding, Winnipeg, Manitoba

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The device described was developed in order to speed up and reduce the work of packaging seed for rod row plots.

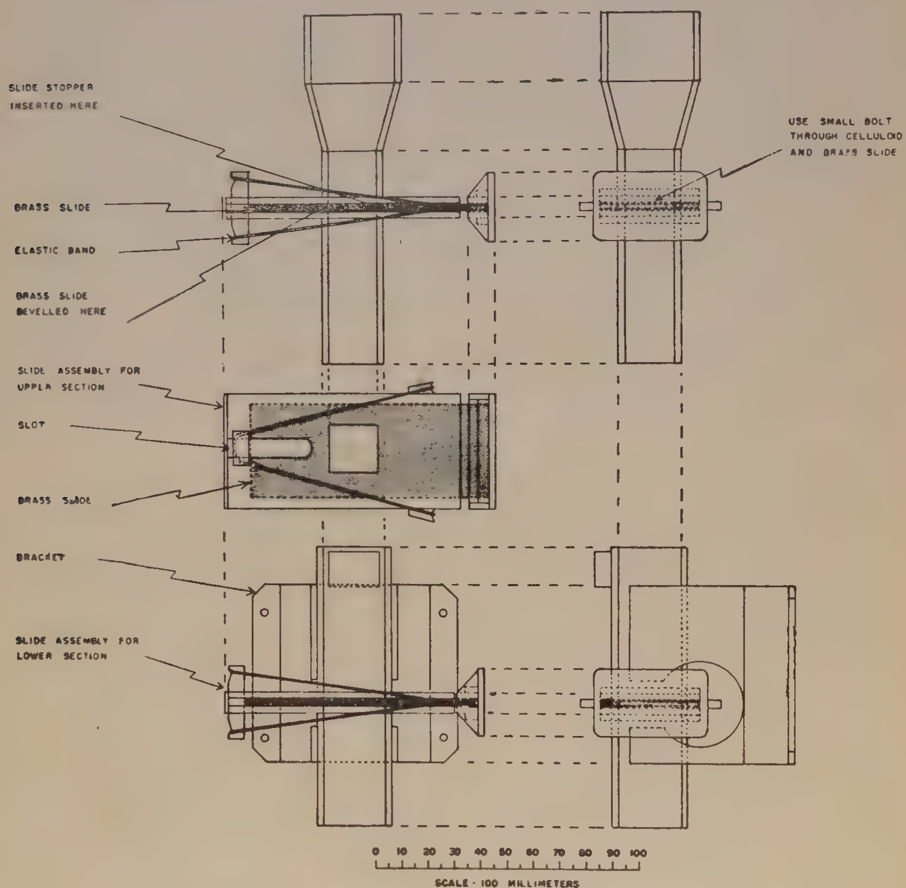

Figure 1. Details of construction of seed dispenser

In order to make rod row plots of different varieties or treatments comparable they should be sown as nearly as possible with the same number of germinable seeds. Previous to the development of the seed dispenser, the procedure followed at this laboratory was first to determine experimentally the average weight of the number of seeds required and then to weigh out the seed for each package. This method was slow and measure-

[1] Contribution No. 134 from the Cereal Division, Dominion Department of Agriculture.
[2] Senior Agricultural Scientist.

ment by volume using cups of varying sizes to dip out the seed was found to be much faster and nearly as accurate as weighing. The next logical step was to make a device that would measure volumes of seed quickly and accurately. After trying various designs the one described was found to be very satisfactory. A number of these have been manufactured at the Central Experimental Farm at Ottawa under the direction of Mr. J. G. C. Fraser, for distribution to Dominion Experimental Stations in Canada.

DESCRIPTION

The basic principle of the device is extremely simple. There is an upper and a lower section of square tubing. The upper one slides inside of the lower one and in each section there is a slide to open up or cut off the flow of seed. Rubber bands hold the slides closed. Pressure on the upper slide allows the seed to flow through and fill up the tube as far as the lower slide. The upper slide is then released and the required volume of seed is then contained in the tube between the two slides. Pressure on the lower slide allows the seed to flow out and on releasing the lower slide the machine is ready for the next load. The volume of seed measured is adjusted by sliding the upper tube in and out of the lower one.

Figure 2 illustrates the seed dispenser in use showing the stand to which it is attached and the large tin funnel which holds the bulk seed. The dispenser slides are operated with two fingers of one hand leaving the other hand free to place envelopes under the delivery spout and to remove them when filled. Envelopes containing sufficient seed for one rod row plot can be filled at approximately 300 per hour.

Details of construction are given in Figure 1. Dimensions can be obtained from the drawing by reference to the millimeter scale. The dimensions are not critical as there is sufficient adjustment to allow for constructional variations. The particular machine described is designed for use with wheat, oats, and barley. A somewhat smaller machine would be more suitable for flax and a larger one for peas or beans.

The material used for the framework of the seed dispenser is sheet celluloid approximately 2.5 millimeters thick. Canadian Industries Limited supply this material under the trade name of Pyralin. The exact thickness of the material is not critical but it should not be less than 2 millimeters as thin material will warp badly in warm weather. Material thicker than 2.5 millimeters is rather difficult to work. The celluloid parts are welded by means of a cement with an acetone base. A satisfactory cement is 40% amyl-acetate and 60% acetone.

Celluloid has distinct advantages as compared to metal for making devices of the kind described. It is more easily cut and welded and its transparency is an advantage in a device such as the seed dispenser where it is desirable to be able to watch the flow of seed.

Two details should be added that are not shown in Figure 1. In the first place it is necessary in order to have sufficient range for the measurement of wheat, oats and barley to make a square inner tube about 40 millimeters long to fit inside of the tube of the upper section. Normally this will be used when measuring wheat but will be out for oats and barley.

FIGURE 2. Seed dispenser in operation

In the second place a suggestion made by Mr. J. G. C. Fraser should be incorporated. This is a threaded rod with a knob or knurled head at one end, for adjusting the volume. A rod of about 3/16 inches in diameter is suggested. The best arrangement seems to be to attach the rod by means of collars to the lower slide assembly and thread it through a portion of the upper slide assembly. Additional celluloid strips can be welded to the slide assemblies for this purpose. In the model shown in Figure 1, adjustments were made by means of a set screw in the block of celluloid shown attached to the lower section. This method is not entirely satisfactory as the set screw tends to push the tube of the upper section out of shape.

Anyone who has not handled sheet celluloid would be well advised before starting to build one of the seed dispensers, to practise for a short time at cutting and welding. The material can be cut by scoring deeply and then breaking. The edges must then be filed smooth before fitting the parts together. The cement is applied freely to the parts to be welded and these are held firmly in place until the cement has hardened.

ACKNOWLEDGMENT

The original models were made by W. A. Clark, now Flt. Sergeant W. A. Clark, Photographic Establishment, Rockcliffe, Ottawa. He was responsible for making and trying out various designs.

IDENTIFICATION OF GRAIN SAMPLES OF HARD RED SPRING WHEAT VARIETIES GROWN IN WESTERN CANADA[1]

R. F. Peterson[2], A. J. Lejeune[3] and H. C. Laidlaw[4]

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It is frequently necessary for those engaged in the production, handling, marketing, grading or testing of grain, either as commercial grain or as seed, to be able to identify samples as to variety. Several years ago instruction on this subject was instituted as part of an agricultural short course given annually by the Division of Plant Science of the University of Manitoba, and the writers were asked to prepare a suitable outline for hard red spring wheat. This was provided in the form of a mimeographed table. As requests for copies of this table have been received from time to time from individuals and from groups interested in wheat, it was thought desirable to publish it.

The outline was prepared originally for the use of farmers, several men employed in the grain trade and others engaged in grain grading and seed testing, all of whom attended the above-mentioned course. The purpose of the outline is to provide a rapid visual method of identifying grain samples of hard red spring wheat varieties commonly occurring in Western Canada, involving a minimum of measurement or statistical work.

MATERIALS AND DEVELOPMENT OF METHODS

The varieties selected for study are listed with their Canadian Accession Numbers in Table 1. Renown and Regent are resistant to stem rust and

Table 1.—Spring wheat varieties and crosses from which they were derived

Variety	Canadian accession number	Cross from which derived
Marquis	1396	Hard Red Calcutta × Red Fife
Reward	1509	Marquis × Prelude
Renown	1915	H-44* × Reward
Regent	1938	H-44* × Reward
Thatcher	1820	(Marquis × Iumillo) × (Marquis × Kanred)
Apex	1857	(H-44 × Double Cross†) × Marquis
Garnet	1316	Preston A × Riga M
Red Bobs	1637	Selected from Early Triumph which appeared to be from a natural cross between Bobs (white-kerneled) and a red-kerneled variety.

* H-44 was derived from the cross Yaroslav Emmer × Marquis.
† Double Cross was derived from the cross (Marquis × Iumillo) × (Marquis × Kanred).

leaf rust: Thatcher and Apex are resistant to stem rust only; and the remaining varieties are susceptible to both rusts. Excellent publications (1, 3, 4, 5) are available dealing with identification of these varieties using the main characteristics of the plant as a whole including the grain. A comprehensive review of literature on identification of wheat species and varieties is given by Clark and Bayles (1).

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[2] Senior Assistant Agricultural Scientist, Dominion Laboratory of Cereal Breeding, Winnipeg, Manitoba.
[3] Lecturer, Division of Plant Science, University of Manitoba.
[4] Assistant Director, Crop Testing Plan, Winnipeg, Manitoba.

Four of these wheats (Marquis, Reward, Garnet and Red Bobs) were included in studies of eleven varieties by Fraser and Gfeller (2) dealing with phenol reactions of spikes and kernels, and with a number of morphological characteristics of kernels. These authors dealt with depth and length of kernel, length of germ, and the angle at which the germ is set, pointing out that in Garnet wheat the germ is "set into the body of the kernel at a more acute angle than any other common wheat usually associated with it in the trade in Canada."

It should be noted here that some of the rust resistant wheats have been modified by selection since they were described in the publications mentioned above. The strain of Regent originally distributed and described was C.A.N. 1902 whereas the strain now commonly grown is C.A.N. 1938. (The corresponding accession numbers at the Dominion Laboratory of Cereal Breeding, Winnipeg, are R.L. 975.1 and R.L. 975.6). C.A.N. 1938, developed from a single plant selection of C.A.N. 1902, has a smaller, smoother kernel than the latter and produces samples of better colour and higher weight per measured bushel. Further improvement in colour and weight per measured bushel has been made by reselection within C.A.N. 1938. A new foundation stock accessioned at Winnipeg as R.L. 975.26 and at Ottawa as C.A.N. 3616 is expected eventually to replace C.A.N. 1938 in the country.

The original Renown C.A.N. 1856 (known also as R.L. 716) was replaced in a similar manner by the selection C.A.N. 1915 (R.L. 716.6) which was superior in leaf rust resistance, strength of straw, yield and quality, but in this case there was little change in kernel characteristics except for greater uniformity.

The stocks of Thatcher and Apex now grown in Western Canada are also more uniform in kernel characteristics than those originally distributed.

As the present study was confined to visual examination of the grain it was found necessary to make use of a larger number of kernel characteristics than is normally used in identification of the plant as a whole. Therefore in preparing the outline presented in this paper a large number of samples grown in Western Canada over a period of years was studied. In some cases complete sets of the eight varieties listed in Table 1 were grown under comparable conditions and samples were available for study.

In addition, a collection of samples was provided by Mr. F. S. Ludlam, Chief Grain Inspector, Inspection Branch, Board of Grain Commissioners for Canada, Winnipeg. Mr. Ludlam greatly assisted in pointing out the grain characteristics which he and his staff had found most useful in identification work, and a number of these have been incorporated in the present outline.

The main difficulties met with in this work were due to (a) the close genetic relationship of most of the varieties and (b) the effect of environment on grain characteristics. As shown in Table 1, the first six varieties consist of Marquis and its derivatives. Accurate identification within this group is often difficult, but it is usually relatively easy to recognize samples of the remaining two wheats, Garnet and Red Bobs. Environment affects all kernel characteristics, causing a range of variation within varieties; and

these varietal ranges overlap to a great extent. This is illustrated strikingly in a coloured plate of Marquis kernels presented by Newman and Fraser (3). In addition to ordinary variations in soil and climate from district to district, disease, drought, or poor growing conditions of any kind tend to obscure varietal differences. However the use of a combination of a relatively large number of characteristics for identification work reduces markedly the uncertainty of identification due to obscure or overlapping characteristics.

Wheat varieties can be identified more easily and accurately from whole plants or heads than from grain samples alone. The methods which follow are therefore intended for use only when nothing but grain samples are available for study.

IDENTIFICATION OF WHEAT SAMPLES

Table 2 presents the outline prepared for use in identifying wheat samples and Figure 1 shows photographs giving four views of representative kernels of each variety. Accurate identification depends mainly on experience and familiarity with the material. The outline presented here cannot take the place of such experience but can only serve as an aid and a guide. It is therefore recommended that, for all varieties discussed above, samples of known identity as well as the photographs in Figure 1 be examined with reference to Table 2 before attempting to use this table to identify unnamed samples. At first all varieties should be examined and compared with respect to individual characteristics, e.g. seed colour. Next the characteristics of each variety are studied collectively. With sufficient experience of this kind, a composite mental picture of the characteristics of grain samples of each variety will be developed, and rapid identification work becomes possible. At the best, however, a degree of error will always remain due to the difficulties already enumerated.

Because of the use for which Table 2 was originally intended the writers have purposely avoided the use of measurement. In presenting such quantitative terms as "short," "mid-long," etc., without defining them in terms of actual units of measurement, it is assumed that the operator will examine samples of known identity and set up approximate mental standards. In the study of length of kernel, for example, average Garnet or Renown samples will be taken as "mid-long" and average Red Bobs or Marquis samples as "short." These concepts then become the standards in dealing with samples of unknown identity. This method has been found practicable because the people for whom the outline has been prepared are already familiar in a general way with the range of variation of colour, kernel size, etc. of wheat samples produced in Western Canada.

Definitions of the various quantitative terms in units of measurement are given by Clark and Bayles (1). The terminology of the present paper will be found to agree in general with that of these authors. Differences will be found to occur, however, because of the two publications being based on samples grown in different environments.

The description of Regent given in Table 2 holds equally well for C.A.N. 1938 and the newer Foundation Stock C.A.N. 3616.

TABLE 2.—KERNEL CHARACTERISTICS OF COMMON WHEAT VARIETIES

(Characteristics most useful in identifying varieties are set in italics)

Variety	Colour	Length and width	Shape	Germ	Crease	Brush	Cheeks	Remarks
Marquis	Medium red	*Short*, wide	Ovate, *brush end truncate* (cut off)	Mid-size	Mid-deep, mid-wide	Mid-size, short to mid-long	Usually rounded, sometimes angular	*Short, plump kernel.* *Slight hump on back, behind germ.* Indistinct longitudinal ridge along one side of back.
Reward	Darker than Marquis, *almost bronze*	Short to mid-long, wide	Ovate, *brush end truncate*	Mid-size, *blunt angle*	Shallow, *narrow*	Small, short	Rounded to angular	*Slightly longer than Marquis.* *Distinct longitudinal ridge on one side of back continuing to form shoulder over germ. Crease side usually flat due to crease being closed.*
Renown	Medium red	Mid-long, mid-wide	Ovate	Mid-size	Shallow, narrow	Mid-size, mid-long	Rounded to angular	*Less distinct ridge on one side of back. Crease side usually flat as in Reward.*
Regent	Medium red	Mid-long, mid-wide	Ovate, brush end truncate	Mid-size	Shallow, wide	Mid-size, mid-long	Angular	*Like Renown but ridge on back less distinct, crease more open, and kernel less smooth.*
Thatcher	Medium red, dull, bleached appearance	Short, mid-wide	*Ovate but almost oval*	Small to mid-size	Mid-deep, wide	Mid-size, short to mid-long	Angular, edge often whitish	*Well-grown samples sometimes have a silvery sheen; others often whitish. Collar around brush. Kernel more nearly oval than in the other varieties.*
Apex	Medium red	Mid-long, mid-wide	Ovate	Mid-size	Mid-deep, mid-wide	Mid-size, mid-long	Rounded to angular	*Like Marquis but lighter colour, longer, more tapered at brush end, and less uniform in size.* Pointed projection at germ end.
Garnet	*Very deep red*	Mid-long, narrow	Ovate to elliptical	Large square, *sharp angle*	Mid-deep, mid-wide	Small, mid-long	Rounded to angular	*Back straight to depressed or only slight hump. Crease side curved from end to end.* (Kernels short and truncate in some districts).
Red Bobs	*Light red*	*Short*, wide	Ovate to oval, *truncate ends*	Large	Mid-deep, mid-wide to wide	Mid-size, short	Usually rounded, sometimes angular	*Short, plump kernel.* *Truncate at both ends.* *Back usually rough.* Samples often contain small deformed kernels. Pit often formed in crease.

DISCUSSION OF INDIVIDUAL CHARACTERISTICS

Colour

There is a wide range from the light red of Red Bobs to the very deep red of Garnet. The name of the latter variety describes its colour very well. Renown has the most translucent and Thatcher the most opaque kernel. The Thatcher kernel commonly has a whitish or grayish colour (as though bleached) combined with the medium red basic colour, although fresh samples grown under the best conditions have a silvery sheen.

Length and Width

Although length and width of kernel vary considerably with different growing conditions, the ratio of length to width is much more constant. This ratio is lowest in Marquis and Red Bobs and highest in Garnet. In badly shrunken kernels all varieties tend to have a high length-width ratio.

In average size of kernel Garnet and Thatcher are smallest and Regent largest.

Shape

The kernels are mostly ovate (egg-shaped) being broader at the germ end than at the brush end, but the tendency of Thatcher kernels to be oval (with equal width at both ends) aids in identifying this variety.

Germ

The germ area is medium in size and tends to be round or oval in shape in most varieties, but is larger and inclined to be somewhat square in Garnet. The angle the germ makes with the longitudinal axis of the kernel is, on the average, sharpest in Garnet and most blunt in Reward. The pointed projection at the end of the germ is most prominent in Apex and least in Red Bobs.

Crease

The depth and width of crease varies greatly within varieties due to different growing conditions. On the average the crease is most closed in Reward and Renown, and most open in Thatcher and Regent. In all varieties a pit is occasionally found in the crease, but it is most common in Red Bobs.

Cheeks

Both rounded and angular cheeks are found in all varieties but the rounded cheek is most commonly found in Marquis, Garnet and Red Bobs. The angular cheek and the whitish line on the edge of the cheek are more frequently found in Thatcher than in the other varieties. Any condition that reduces the plumpness of kernel in wheat varieties tends to produce angular cheeks.

Brush

Although the area of brush and length of brush hairs vary within varieties, average varietal differences are sufficiently constant to be useful in identification work. The collar around the brush is most prominent in Thatcher, but a less distinct collar may be found in some samples of the other varieties.

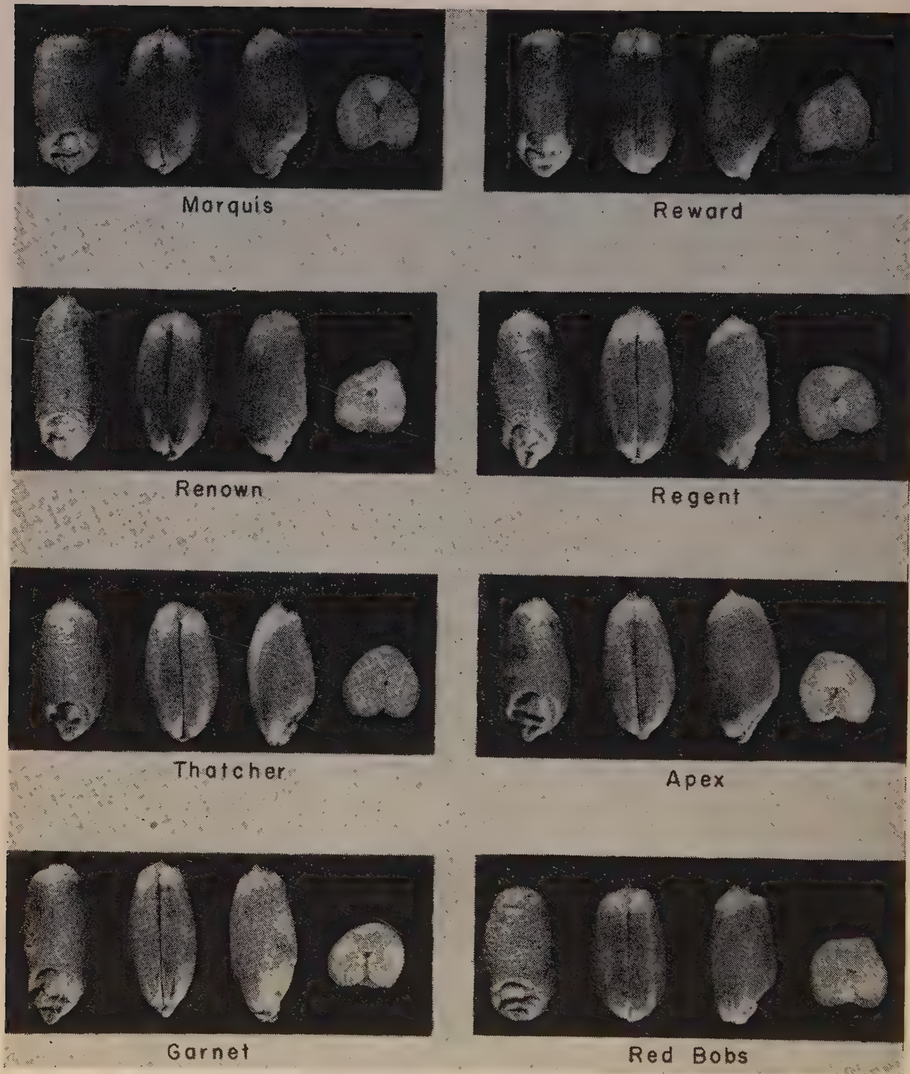

FIGURE 1. Dorsal, ventral, lateral, and cross-sectional views of representative kernels of eight hard red spring wheat varieties.

Back

The position of the relatively sharp longitudinal ridge along one side of the back of Reward and Renown kernels is clearly shown in Figure 1. A less distinct one-sided development of the back is characteristic of the other varieties. However, all eight varieties display a sharp ridge if the kernels are somewhat shrunken.

The back of Red Bobs kernels is usually comparatively rough.

SUMMARY

A non-technical outline is presented to aid those engaged in the wheat industry to identify, as to variety, grain samples of hard red spring wheats commonly grown in Western Canada.

It is suggested that a preliminary examination of samples of known varieties with reference to the outline will enhance the operator's ability to use it in identifying samples of unknown identity.

ACKNOWLEDGMENTS

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EFFECTS OF CULTIVATION AND CROPPING ON THE CHEMICAL COMPOSITION OF SOME WESTERN CANADA PRAIRIE PROVINCE SOILS. PART III[1]

J. D. Newton[2], F. A. Wyatt[3], and A. L. Brown[4]

University of Alberta and Dominion Experimental Farms Service

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Soil deterioration has always been a problem in agriculture because maintenance of soil fertility is essential for any system of permanent agriculture.

Comparatively few actual determinations of the extent of the losses of soil organic matter in the Prairie Provinces of Canada had been made prior to the initiation of this investigation, although it is recognized that soil organic matter is the main natural source of available plant food, that it increases the moisture holding capacity of soils, reduces or prevents erosion by wind or water (if fibrous) and otherwise improves the physical properties of soils. It was decided that the extent of the losses *should* be determined because the future of agriculture in these provinces, including the satisfactory rehabilitation of soldier farmers following the cessation of hostilities, depends largely upon maintenance of soil fertility. An extensive investigation was therefore undertaken to determine by chemical analysis of some cropped and virgin soils what effects the present methods of farming have had on the organic matter of the soil, and on some total and available or easily soluble plant foods.

Farming practices have been very similar over wide areas of the three prairie provinces. They consist mainly of grain and fallow systems said by many to be wasteful of soil fertility.

Reference was made in the first paper in this series (3) to evidence obtained in Britian, the United States, and Canada, of losses of nitrogen and organic carbon from soils resulting from cultivation and cropping.

Recently DeTurk (4) reported that on the Morrow plots at Illinois, with continuous corn, corn-oats rotation, and corn-oats-red clover rotation, during the past 29 years the organic carbon of the surface soil had remained practically constant on both the fertilized and unfertilized plots of the 3-year rotation. A similar constancy occurred on the fertilized portion of the 2-year rotation. In the other plots the organic carbon was found to undergo a progressive decline. Total nitrogen was found to follow the organic carbon rather closely. Total phosphorus also declined more under continuous corn than under a corn-oats rotation or a corn-oats-clover rotation.

Metzger (7, 8) in Kansas studied the influence of cropping systems and soil treatments on the nitrogen and organic carbon of soils. Losses occurred in some rotations and under continuous wheat, but alfalfa grown continuously increased the soil's supply of nitrogen and organic carbon over a period of 19 years.

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[1] Contribution from Dominion Department of Agriculture, Experimental Farms Service, P.F.R.A., in co-operation with the University of Alberta, Department of Soils.
[2] Professor of Soils.
[3] Professor of Soils.
[4] Research Assistant, P.F.R.A., Dominion Experimental Farms (now with Division of Soils, University of Minnesota).

Salisbury and DeLong (11) in studing virgin and cultivated soils found only small losses of organic matter as a result of cultivation.

In the first report on this investigation (3) the total organic carbon and nitrogen analyses of cultivated and virgin samples from 34 widely scattered points in Alberta and Saskatchewan were published, and it was show that on the average fairly large losses of these two constituents had occurred under cultivation.

More recent work on this problem has been extended to include Manitoba and the Peace River district of Alberta. Samples have also been collected from more recently broken fields and adjacent uncultivated soil in order to obtain estimations of the rates of loss, and to determine whether the rate of loss is most rapid after the land is first broken. A preliminary outline of some of the more recent work on this project was published as Part II of this series (2).

In this paper some of the data showing effects of cultivation and cropping on chemical composition of soils, published in the first report of this investigation (3) are repeated for purposes of direct comparison with previously unpublished data. This has been done in many cases in order to compare effects of a relatively short period of cultivation with the previously reported effects of cultivation for many years, in the same district or location.

While obvious erosion, both by wind and water, plays a great part in soil depletion, it is outside the scope of this investigation. This particular project has been chiefly concerned with losses from cultivated soil due to decomposition of organic matter together with volatilization and leaching, and removal of essential plant nutrients by crops. However, it is quite likely that erosion often plays a part in soil deterioration under cultivation even when the effects are not readily observable.

METHODS

Soil Samples

Up to the present, samples from 85 locations, representing 85 comparisons of virgin and cultivated soil, have been collected from various points in Alberta, Saskatchewan and Manitoba. The investigation has involved the chemical analysis of more than 1000 composite or individual samples of soil.

Duplicate samples of relatively old cultivated and nearby virgin soil were obtained at each location. Also in 22 cases similar samples of more recently broken fields and corresponding virgin soil were obtained at or near the same location in order to study rates of loss. Duplicate composite samples of surface soil were obtained in all cases, and in most cases composite samples of the second or 6- to 12-inch depth were obtained also. Each composite was made up of a mixture of 10 or more well mixed replicate samples taken at random within the sampled area. The adjacent areas of cultivated and uncultivated soil from which composite samples were taken each consisted of not more than 1/10 acre as a rule, and were usually separated by a fence or roadway. For the most part the samples obtained were taken in the field according to profile, but in some cases the surface horizon was divided, and in others two and even part of a third horizon were combined to make up the ploughing depth. The average plough depth was taken as 6 to 7 inches.

Samples of the subsoil (below the depth of 12 inches) were obtained, but it was considered better not to include the subsoil composition in the tables which show the effects of cultivation, since the composition of the subsoil would probably not be affected by cultivation nearly as much as the composition of the surface soil. Moreover, since composite samples of subsoil were not obtained as a rule, the composition of the single samples obtained would be less representative, and, if included, would tend to increase the error or obscure the effects of cultivation. However, the subsoil samples were analysed for total organic carbon and nitrogen, and, in some cases, other elements. These analyses will be published later in order to indicate the character of the subsoil.

An attempt was made to sample cultivated and adjacent uncultivated soils that were uniform in texture and profile, and free from erosion or drifting. It is probably impossible to avoid erosion or drifting entirely, but the appearance of the profile and surrounding soil will usually show whether this has been appreciable.

Something of the history of the field was always obtained, such as length of time cultivated, types of crops grown, rotations used, fertilizers and manures applied, if any. Usually, fertilized fields were avoided since this would complicate the particular problem.

The samples were taken to the laboratory, where the larger stones and heavier debris were removed. They were then air-dried, well mixed, and a portion of each sample was finely ground in a Braun pulverizer for chemical analyses.

All samples were analysed for organic carbon and total nitrogen. The results of these analyses are given in this paper and in previously published papers (2, 3). Carbon to nitrogen ratios have been calculated from the percentages of organic carbon and total nitrogen.

Many of the samples have been analysed for total phosphorus, easily soluble phosphorus, water-soluble phosphorus, total sulphur, and pH values. Nitrification studies and carbon dioxide evolution studies have also been carried out with some of the surface samples. These results will be published in subsequent papers.

Organic Carbon

Organic carbon was determined by Schollenberger's chromic acid reduction method as modified by Allison (1). Organic matter was calculated by multiplying organic carbon by the factor 1.724.

Total Nitrogen

The total nitrogen was determined by the Kjeldahl-Gunning-Hibbard method, modified by the addition of selenium as a catalyst (9).

RESULTS

Total Organic Carbon, Organic Matter, and Nitrogen

All samples of soil were analysed for total organic carbon in order to determine their organic matter content. The organic carbon contents of the upper 6 inches and of the subsurface 6 to 12 inches, and the organic matter content of the upper 12 inches of soil, in the different soil zones, are

shown in Tables 1 to 6. The averages of the different soil zones are shown in Table 7 for convenient comparison of the organic carbon and organic matter of the soils of the different zones.

TABLE 1.—LOSS OR GAIN OF ORGANIC CARBON IN CULTIVATED BROWN SOILS

Location	Surface soil class	Years cult.	0"–6"			6"–12"			0"–12"	
			Orig. %	Loss or gain		Orig. %	Loss or gain		Loss or gain Lb./acre	
				% of orig.	Lb./acre		% of orig.	Lb./acre	Organic carbon	Organic matter
Brooks	L.	12	2.18	−42	−16,470	1.50	− 3	− 8,010	−24,480	−42,228
Brooks	L.	3	3.63	−11	− 8,000	1.06	+ 8	+ 1,700	−6,300	−10,868
Cabri	C.	26	1.27	− 2	− 4,590	0.99	− 8	− 1,440	−6,030	−10,402
Cabri	C.	13	1.39	−10	− 2,800	0.95	− 1	−100	−2,900	− 5,003
Cavendish	F.S.L.	23	1.78	−28	− 9,060	1.09	− 4	−810	−9,870	−17,026
Cavendish	F.S.L.	11	1.74	− 4	− 1,300	0.81	+15	+ 2,500	+1,200	+ 2,070
Gros Ventre	L.	20	4.06	−43	−31,320	1.24	−28	− 6,300	−37,620	−64,895
Gros Ventre	L.	9	3.81	−51	−38,500	0.96	− 7	− 1,400	−39,900	−68,828
Swift Current	L.	15	3.42	+ 2	+ 1,260	1.31	−21	− 5,940	−4,680	− 8,073
Swift Current	L.	30	5.35	−38	−36,990	1.27	+ 2	+360	−36,630	−63,187
Swift Current	L.	14	3.53	− 2	− 1,500	2.12	−28	−11,700	−13,200	−22,770
Average of 11 locations		16	2.92	−21	−13,570	1.21	− 7	− 2,831	−16,401	−28,292
Average of all samples (13 locations)		—	—	−22	−11,943	—	−13	− 2,878	−14,821	−25,566

TABLE 2.—LOSS OR GAIN OF ORGANIC CARBON IN CULTIVATED DARK BROWN SOILS

Location	Surface soil class	Years cult.	0"–6"			6"–12"			0"–12"	
			Orig. %	Loss or gain		Orig. %	Loss or gain		Loss or gain Lb./acre	
				% of orig.	Lb./acre		% of orig.	Lb./acre	Organic carbon	Organic matter
Cutknife	L.	31	4.50	−32	−26,010	1.59	−25	− 6,600	−32,610	−56,252
Cutknife	L.	4	4.35	+ 2	+ 1,700	1.65	+10	+ 3,400	+5,100	+ 8,798
Edgerton	L.	26	4.21	−19	−14,220	2.26	−16	− 5,370	−19,590	−33,793
Edgerton	L.	12	5.50	−25	−27,300	2.23	− 6	− 2,800	−30,100	−51,923
Estevan	L.	33	4.54	−49	−44,200	1.19	−43	−10,200	−54,400	−93,840
Hand Hills	L.	20	3.01	− 3	− 1,700	1.93	−11	− 4,000	−5,700	− 9,833
Hand Hills	L.	9	4.72	−32	−30,100	1.23	+13	+ 3,300	−26,800	−46,230
Hanley	L.	30	2.22	−12	− 5,500	1.04	−11	− 2,200	−7,700	−13,283
Hanley	L.	6	4.48	+ 4	+ 3,400	1.94	− 8	− 3,100	+300	+518
Lethbridge Rotation U	L.	25*	2.52	−14	− 6,679	1.65	− 2	−141	−6,820	−11,765
Lethbridge Rotation C	L.	26*	2.56	−39	−18,000	1.18	0	+180	−17,820	−30,740
Lethbridge	L.	8	2.53	+ 2	+800	1.20	+26	+ 6,100	+6,900	+11,903
Morrin	C.	26	4.90	−30	−26,370	2.17	− 4	− 1,710	−28,080	−48,438
Morrin	C.	13	3.60	−14	−10,400	2.20	−22	− 9,500	−19,900	−34,328
Regina E.	L.	49	4.32	−40	−31,400	1.09	−21	− 4,140	−35,540	−61,307
Regina E.	L.	15	5.01	−28	−27,600	1.81	−25	− 9,000	−36,600	−63,135
Regina S.	C.	50	3.37	−49	−29,790	1.52	− 1	−360	−30,150	−52,009
Regina N.	C.	5	4.60	−13	−11,500	2.08	+11	+ 4,500	−7,000	−12,075
Waskada	L.	30	5.21	−28	−29,400	2.89	+ 4	+ 2,100	−27,300	−47,093
Average of 19 locations		22	4.01	−22	−17,593	1.73	− 7	− 2,081	−19,674	−33,938
Average of all samples (20 locations)		—	—	−21	−16,209	—	− 8	− 2,509	−18,718	−32,289

* Years under this rotation.

TABLE 3.—LOSS OR GAIN OF ORGANIC CARBON IN CULTIVATED BLACK SOILS

Location	Surface soil class	Years cult.	0″–6″ Orig. %	0″–6″ Loss or gain % of orig.	0″–6″ Loss or gain Lb./acre	6″–12″ Orig. %	6″–12″ Loss or gain % of orig.	6″–12″ Loss or gain Lb./acre	0″–12″ Loss or gain Lb./acre Organic carbon	0″–12″ Loss or gain Lb./acre Organic matter
Brandon	F.S.L.	50+	5.86	−34	−39,600	2.65	−19	− 9,900	−49,500	−85,388
Indian Head Rot. R.	C.L.	29*	3.03	−26	−15,900	2.48	−15	− 7,300	−23,200	−40,020
Indian Head Rot. C.	C.L.	29*	3.53	−29	−20,800	3.57	−42	−30,300	−51,100	−88,148
Lacombe Rot. C.	C.L.	25*	7.39	− 8	−11,160	6.86	−21	−25,380	−36,540	−63,032
Lacombe Rot. O.	O.L.	26*	5.13	+ 3	+ 2,600	3.23	+13	+ 7,900	+10,500	+18,113
Lloydminster	L.	5	7.29	−10	−15,000	2.93	−25	−14,800	−29,800	−51,405
Lloydminister	L.	32	6.79	−25	−34,400	2.14	+21	+ 9,200	−25,200	−43,470
Melfort	L.	30	8.36	−16	−24,120	4.77	+12	+ 9,930	−14,190	−24,478
Melfort	L.	4	7.76	−27	−43,200	2.74	−26	−14,000	−57,200	−98,670
Parkland	L.	27	5.86	−43	−45,540	2.38	−23	− 9,810	−55,350	−95,479
Parkland	L.	10	4.21	− 8	− 7,000	1.58	− 3	− 1,100	−8,100	−13,973
Pincher Creek	Si. L.	27	7.97	−38	−53,820	2.39	−13	− 9,120	−62,940	−108,572
Pincher Creek	Si. L.	13	7.03	−44	−62,300	3.45	−42	−28,700	−91,000	−156,975
Portage la Prairie	Si. L.	50+	5.38	−20	−21,100	3.34	−16	−10,900	−32,000	−55,200
Selkirk	C.L.	24	8.96	−30	−53,300	4.85	−27	−25,900	−79,200	−136,620
Vegreville	L.	30	6.94	−17	−23,982	2.91	−13	− 7,754	−31,736	−54,745
Vegreville	L.	9	6.94	−14	−19,432	2.93	0	−100	−19,532	−33,673
Winkler	L.	50+	3.20	+14	+ 8,700	4.16	−17	−14,400	−5,700	− 9,833
Yorkton	L.	40	5.80	−22	−25,000	2.71	−12	− 6,400	−31,400	−54,165
Yorkton	L.	10	5.96	− 6	− 7,600	3.73	−32	−23,600	−31,200	−53,820
Average of 20 locations		26	6.09	−18	−25,598	3.16	−11	−10.622	−36,220	−62,443
Average of all samples (22 locations)		—	—	−19	−27,526	—	−10	− 8,979	−36,505	−62,935

Years under this rotation.

TABLE 4.—LOSS OR GAIN OF ORGANIC CARBON IN CULTIVATED BLACK-TRANSITION SOILS

Location	Surface soil class	Years cult.	0″–6″ Orig. %	0″–6″ Loss or gain % of orig.	0″–6″ Loss or gain Lb./acre	6″–12″ Orig. %	6″–12″ Loss or gain % of orig.	6″–12″ Loss or gain Lb./acre	0″–12″ Loss or gain Lb./acre Organic carbon	0″–12″ Loss or gain Lb./acre Organic matter
Fairview	Si. L.	11	8.63	−34	−59,200	2.05	−26	−10,500	−69,700	−120,233
Fairview	Si. L.	28	9.10	−34	−62,700	2.91	−31	−18,100	−80,800	−139,380
Beaverlodge	C.L.	21	7.32	−10	−14,400	1.55	−12	− 3,800	−18,200	− 31,395
Grande Prairie	Si. L.	25	4.09	−12	−10,100	1.25	−10	− 2,600	−12,700	− 21,908
High Prairie	C.L.	11	11.43	−22	−51,300	3.41	−25	−17,000	−68,300	−117,818
High Prairie	C.L.	29	11.36	−45	−103,100	2.27	−13	− 6,000	−109,100	−188,198
Dauphin	C.L.	45	7.32	−12	−17,400	5.12	+ 2	+ 2,400	− 15,000	− 25,875
Average of 7 locations		24	8.46	−24	−45,457	2.65	−16	− 7,943	− 53,400	− 92,115
Average of all samples (7 locations)		—	—	−24	−45,457	—	−16	− 7,943	− 53,400	− 92,115

TABLE 5.—LOSS OR GAIN OF ORGANIC CARBON IN CULTIVATED GRAY-TRANSITION SOILS

Location	Surface soil class	Years cult.	0″–6″ Orig. %	0″–6″ Loss or gain % of orig.	0″–6″ Loss or gain Lb./acre	6″–12″ Orig. %	6″–12″ Loss or gain % of orig.	6″–12″ Loss or gain Lb./acre	0″–12″ Loss or gain Lb./acre Organic carbon	0″–12″ Loss or gain Lb./acre Organic matter
Debolt	C.L.	20	2.65	+ 6	+ 3,400	0.83	+12	+2,000	+5,400	+ 9,315
Debolt	C.L.	5	2.65	+26	+13,700	0.83	− 8	−1,300	+12,400	+21,390
Nampa	H.C.L.	19	7.25	−36	−52,800	1.29	− 1	−200	−53,000	−91,425
Nampa	H.C.L.	5	7.25	−43	−61,800	1.29	+20	+5,100	−56,700	−97,808
Average of 4 locations		12	4.95	−12	−24,375	1.06	+ 6	+1,400	−22,975	−39,632
Average of all samples (4 locations)		—	—	−12	−24,375	—	+ 6	+1,400	−22,975	−39,632

TABLE 6.—LOSS OR GAIN OF ORGANIC CARBON IN CULTIVATED GRAY SOILS

Location	Surface soil class	Years cult.	0″–6″ Orig. %	0″–6″ Loss or gain % of orig.	0″–6″ Loss or gain Lb./acre	6″–12″ Orig. %	6″–12″ Loss or gain % of orig.	6″–12″ Loss or gain Lb./acre	0″–12″ Loss or gain Lb./acre Organic carbon	0″–12″ Loss or gain Lb./acre Organic matter
Breton C-1	Si. L.	14	2.69	−51	−24,750	0.81	−33	−4,875	−29,625	−51,103
Breton C-3*	Si. L.	14	2.69	−49	−23,580	0.81	−35	−4,980	−28,560	−49,266
Breton E-1	Si. L.	14	2.75	−49	−27,100	0.88	−23	−4,100	−31,200	−53,820
Breton E-3*	Si. L.	14	2.75	−48	−26,100	0.88	−27	−4,700	−30,800	−53,130
Breton	Si. L.	15	2.19	−17	− 7,300	0.69	− 4	−500	− 7,800	−13,455
Carrot Creek	Si. L.	5	2.05	− 4	− 1,700	0.70	− 1	−200	− 1,900	− 3,278
Cherhill	Si. L.	11	2.13	−18	− 7,800	0.77	− 5	−800	− 8,600	−14,835
Edson	Si. L.	24	1.32	−36	− 9,500	0.57	− 8	−900	−10,400	−17,940
Goodfare	Si. L.	21	2.63	−37	−19,600	1.33	−29	−7,700	−27,300	−47,093
Gunn	L.	11	3.19	−18	−11,200	0.90	−13	−2,300	−13,500	−23,288
Love	Si. L.	7	2.62	−36	−18,600	0.86	−30	−1,200	−19,800	−34,155
Mackay	Si. L.	3	1.81	−10	− 3,240	0.66	+ 6	+735	− 2,505	− 4,321
Mackay	Si. L.	14	2.74	+16	+ 8,900	0.83	−10	+1,600	+10,500	+18,113
Average of 13 locations		13	2.43	−27	−13,198	0.82	−16	−2,302	−15,499	−26,736
Average of all samples (19 locations)		—	—	−29	−13,850	—	−18	−2,538	−16,388	−28,253

* Complete fertilizer applied annually for last 9 years.

When all previously published analyses are included the average loss figures are changed as shown in the tables, but only to a small extent.

Only a relatively small number of samples was obtained from locations within the black-transition and gray-transition soil zones (or sub-zones), and consequently the averages obtained from the analyses of these samples are less representative than those of the other soil zones. Moreover, the soils within the transition zones are frequently quite variable in composition. Those of the black-transition zone usually possess many of the charac-

TABLE 7.—AVERAGE LOSSES OF ORGANIC CARBON AND ORGANIC MATTER FROM CULTIVATED SOILS OF DIFFERENT SOIL ZONES

Soil zone	No. locations sampled	Av. no. years cult.	0"–6" Organic carbon Orig. %	0"–6" Av. loss % of orig.	0"–6" Av. loss Lb. per acre	6"–12" Organic carbon Orig. %	6"–12" Av. loss % of orig.	6"–12" Av. loss Lb. per acre	0"–12" Av. loss Lb./acre Organic carbon	0"–12" Av. loss Lb./acre Organic matter
Brown	11	16	2.92	21	13,570	1.21	7	2,831	16,401	28,292
Brown	13	—	—	22	11,943	—	13	2,878	14,821	25,566
Dark brown	19	22	4.01	22	17,593	1.73	7	2,081	19,674	33,938
Dark brown	20	—	—	21	16,209	—	8	2,509	18,718	32,289
Black	20	26	6.09	18	25,598	3.16	11	10,622	36,220	62,443
Black	22	—	—	19	27,526	—	10	8,979	36,505	62,935
Black-transition	7	24	8.46	24	45,457	2.65	16	7,943	53,400	92,115
Gray-transition	4	12	4.95	12	24,375	1.06	6	1,400	22,975	39,632
Gray	13	13	2.43	27	13,198	0.82	16	2,302	15,499	26,736
Gray	19	—	—	29	13,850	—	18	2,538	16,388	28,253

teristics of the black soil zone and those of the gray-transition zone many of the characteristics of the gray soil zone. Most of the black-transition soils sampled were exceptionally rich in organic matter.

A statistical analysis of the data has shown that the average losses of organic carbon or organic matter from the surface 6 inches of the brown, dark brown, black (including black-transition), gray (including gray-transition) and gray soils, are significant in all cases, and that the losses from the subsurface, or 6- to 12-inch depth are significant in all cases also (Table 8).

TABLE 8.—SIGNIFICANCE OF LOSSES OF CARBON FROM CULTIVATED SOILS OF DIFFERENT SOIL ZONES (SURFACE AND SUBSURFACE LAYERS)

Soil zone	Depth	No. cult. fields or locations	Av. no. years cult.	Av. total loss	Min. sig. loss*
				%	%
Brown	0"– 6"	11	18.7	0.65	0.50
Brown	6"–12"	10	18.4	0.14	0.14
Dark brown	0"– 6"	19	21.4	0.90	0.35
Dark brown	6"–12"	18	22.2	0.13	0.11
Black (including black-transition)	0"– 6"	31	24.8	1.39	0.45
Black (including black-transition)	6"–12"	30	25.5	0.55	0.34
Gray (including gray-transition)	0"– 6"	19	14.3	0.73	0.44
Gray (including gray-transition)	6"–12"	18	14.9	0.13	0.10
Gray	0"– 6"	13	13.5	0.49	0.31
Gray	6"–12"	12	14.3	0.14	0.08

*At 5% level of significance.

TABLE 9.—LOSS OR GAIN OF NITROGEN IN CULTIVATED BROWN SOILS

Location	Surface soil class	Years cult.	0″–6″ Orig. %	0″–6″ Loss or gain % of orig.	0″–6″ Loss or gain Lb./acre	6″–12″ Orig. %	6″–12″ Loss or gain % of orig.	6″–12″ Loss or gain Lb./acre	0″–12″ Loss or gain Lb./acre
Brooks	L.	12	.159	−32	−1044	.111	−18	−414	−1458
Brooks North	L.	3	.294	− 7	− 440	.113	+14	+310	− 130
Cavendish	F.S.L.	23	.143	−18	− 441	.099	+13	+234	− 207
Cavendish	L.	11	.153	+ 4	+ 130	.077	+37	+570	+ 700
Gros Ventre	L.	20	.291	−36	−1890	.111	−29	−594	−2484
Gros Ventre	L.	9	.292	−43	−2510	.090	− 1	− 10	−2520
Cabri	C.	26	.134	−21	− 162	.106	− 6	− 42	− 204
Cabri	C.	13	.155	− 3	− 80	.117	+ 5	+120	+ 40
Swift Current	L.	30	.394	−33	−2340	.104	+ 9	+171	−2169
Swift Current	L.	14	.308	− 6	− 340	.200	−30	−1200	−1540
Swift Current	L.	15	.266	+ 2	+ 90	.114	−24	−378	− 288
Average of 11 locations		16	.235	−18	− 820	.113	− 3	−112	− 933
Average of all samples (13 locations)		—	—	−17	− 779	—	− 5	−110	− 889

TABLE 10.—LOSS OR GAIN OF NITROGEN IN CULTIVATED DARK BROWN SOILS

Location	Surface soil class	Years cult.	0″–6″ Orig. %	0″–6″ Loss or gain % of orig.	0″–6″ Loss or gain Lb./acre	6″–12″ Orig. %	6″–12″ Loss or gain % of orig.	6″–12″ Loss or gain Lb./acre	0″–12″ Loss or gain Lb./acre
Lethbridge Rotation C	Si. L.	26*	.206	−37	−1368	.102	+12	+126	−1242
Lethbridge	Si. L.	8	.217	+ 6	+ 270	.122	+25	+610	+ 880
Lethbridge Rotation U	Si. L.	25*	.209	− 6	− 275	.153	+ 1	+ 60	− 215
Morrin	C.	26	.413	−21	−1750	.213	+ 3	+120	−1630
Morrin	C.	13	.327	− 8	− 550	.230	−15	−710	−1260
Hand Hills	L.	20	.221	+ 1	− 168	.144	− 7	+122	− 46
Hand Hills	L.	9	.351	−27	−1890	.126	+ 8	+200	−1690
Edgerton	L.	26	.336	− 9	− 540	.193	− 6	− 42	− 582
Edgerton	L.	12	.421	−22	−1880	.179	+ 1	+ 30	−1850
Cutknife	L.	31	.336	−28	−1692	.121	−23	−492	−2184
Cutknife	L.	4	.342	+ 6	+ 410	.147	+10	+280	+ 690
Hanley	L.	30	.194	− 7	− 290	.099	− 7	−140	− 430
Hanley	L.	6	.369	+ 4	+ 300	.176	− 5	−190	+ 110
Regina South	C.	50	.313	−43	−2412	.164	− 5	−162	−2574
Regina North	C.	5	.402	− 7	− 580	.224	+ 7	+330	− 250
Regina East	L.	49	.327	−39	−2286	.088	−13	−198	−2484
Regina East	L.	15	.417	−25	−2080	.174	−14	−500	−2580
Estevan	L.	33	.371	−42	−3150	.115	−25	−590	−3740
Waskada	L.	30	.428	−24	−2030	.254	+ 7	+370	−1660
Average of 19 locations		—	.326	−17	−1156	.159	− 2	− 41	−1197
Average of all samples (20 locations)		—	—	−18	−1173	—	− 1	− 35	−1208

*Years under this rotation.

The black and black-transition soils have lost most organic matter whereas the brown and gray soils have lost the least (Table 7). Thus it will be observed that the losses increase with increase in original organic matter content.

Both total losses and percentage of original organic carbon content losses from the subsurface or 6- to 12-inch depth were small on the average as compared to the losses from the upper 6-inch depth (Table 7).

The losses in percentage of original organic carbon content from the surface 6 inches of brown, dark brown, and black soils were much alike on the average, and amounted to about 20% of the original content (Table 7).

The losses in percentage of original organic carbon content from the surface 6 inches were greatest in the case of the gray soils, amounting on the average to about 29% of the original content (Table 7).

All samples of soil were analysed for total nitrogen. The total nitrogen contents of the upper 6 inches, the subsurface 6 to 12 inches, and the upper 12 inches of soil in the different soil zones are shown in Tables 9 to 14. The averages of the different soil zones are shown in Table 15 for convenient comparison of the total nitrogen contents of the soils of the different zones.

Table 11.—Loss or gain of nitrogen in cultivated black soils

Location	Surface soil class	Years cult.	0″–6″ Orig. %	0″–6″ Loss or gain % of orig.	0″–6″ Loss or gain Lb./acre	6″–12″ Orig. %	6″–12″ Loss or gain % of orig.	6″–12″ Loss or gain Lb./acre	0″–12″ Loss or gain Lb./acre
Pincher Creek	Si. L.	27	.577	−20	−3222	.242	−21	−507	−3729
Pincher Creek	Si. L.	13	.554	−41	−4560	.289	−33	−1910	−6470
Parkland	L.	27	.440	−41	−3250	.151	+ 6	+ 170	−3080
Parkland	L.	10	.344	− 5	− 330	.143	− 2	− 60	− 390
Lacombe, Rotation C	L.	25*	.552	− 3	− 270	.413	− 1	−100	− 370
Lacome, Rotation O	L.	26*	.412	+ 7	+ 560	.276	− 1	− 80	+ 480
Vegreville	L.	30	.506	−16	−1582	.151	−15	− 443	−2025
Vegreville	L.	9	.506	− 8	− 860	.219	+ 8	+360	− 500
Lloydminster	L.	31	.549	−27	−3000	.297	−45	−2760	−5760
Lloydminster	L.	5	.592	− 6	− 760	.256	−22	−1130	−1890
Melfort	L.	30	.646	−16	−1818	.374	+18	+1242	− 576
Melfort	C.L.	4	.614	−25	−3060	.235	−23	−1060	−4120
Yorkton	L.	40	.512	−24	−2500	.242	− 8	− 380	−2880
Yorkton	L.	10	.514	− 6	− 570	.341	−29	−1970	−2540
Indian Head, Rotation R	C.L.	29*	.279	−20	−1100	.240	−14	− 650	−1750
Indian Head, Rotation C	C.L.	29*	.314	−28	−1770	.312	−38	−2360	−4130
Brandon	F.S.L.	50	.456	−33	−2980	.219	−17	− 760	−3740
Portage la Prairie	Si. L.	50	.427	−15	−1280	.272	−13	− 720	−2000
Winkler	L.	50	.266	+ 8	+ 450	.334	−18	−1210	− 760
Selkirk	C.L.	24	.709	−27	−3880	.400	−24	−1890	−5770
Average of 20 locations		26	.487	−17	−1789	.270	−15	− 811	−2600
Average of all samples (22 locations)		—	—	−18	−1891	—	−15	− 767	−2658

* Years under this rotation.

TABLE 12.—LOSS OR GAIN OF NITROGEN IN CULTIVATED BLACK-TRANSITION SOILS

Location	Surface soil class	Years cult.	0″–6″ Orig. %	0″–6″ Loss or gain % of orig.	0″–6″ Loss or gain Lb./acre	6″–12″ Orig. %	6″–12″ Loss or gain % of orig.	6″–12″ Loss or gain Lb./acre	0″–12″ Loss or gain Lb./acre
Fairview	Si. L.	11	.797	−34	−5380	.192	−15	−580	−5960
Fairview	Si. L.	28	.797	−33	−5210	.277	−28	−1560	−6770
Beaverlodge	C.L.	21	.697	− 7	−1000	.146	− 3	− 80	−1080
Grande Prairie	Si. L.	25	.361	− 1	− 80	.138	− 5	− 140	− 220
High Prairie	C.L.	29	.843	−43	−7280	.177	− 9	− 310	−7590
High Prairie	C.L.	11	.857	−12	−2170	—	—	—	—
Dauphin	C.L.	45	.644	− 7	− 900	.456	+ 6	+ 550	− 350
Average of 7 locations		24	.714	−20	−3146	.231	− 9	− 353	−3662
Average of all samples (7 locations)		—	—	−20	−3146	—	− 9	−353	−3662

TABLE 13.—LOSS OR GAIN OF NITROGEN IN CULTIVATED GRAY-TRANSITION SOILS

Location	Surface soil class	Years cult.	0″–6″ Orig. %	0″–6″ Loss or gain % of orig.	0″–6″ Loss or gain Lb./acre	6″–12″ Orig. %	6″–12″ Loss or gain % of orig.	6″–12″ Loss or gain Lb./acre	0″–12″ Loss or gain Lb./acre
Nampa	C.L.	19	.602	−32	−3870	.161	+ 8	+260	−3610
Nampa	C.L.	5	.602	−28	−3380	.161	+18	+590	−2790
Debolt	H.C.L.	20	.278	−64	−3530	.099	+ 4	+ 70	−3460
Debolt	H.C.L.	5	.278	+ 1	+ 80	.099	− 2	− 40	+ 40
Average of 4 locations		—	.440	−31	−2675	.130	+ 7	+220	−2455
Average of all samples (4 locations)		—	—	−31	−2675	—	+ 7	+220	−2455

TABLE 14.—LOSS OR GAIN OF NITROGEN IN CULTIVATED GRAY SOILS

Location	Surface soil class	Years cult.	0″–6″ Orig. %	0″–6″ Loss or gain % of orig.	0″–6″ Loss or gain Lb./acre	6″–12″ Orig. %	6″–12″ Loss or gain % of orig.	6″–12″ Loss or gain Lb./acre	0″–12″ Loss or gain Lb./acre
Breton C-1	Si. L.	14	.148	−43	−1152	.052	−34	−312	−1464
Breton C-3*	Si. L.	14	.148	−41	−1098	.052	−30	−273	−1371
Breton E-1	Si. L.	14	.151	−30	− 910	.064	−11	−140	−1050
Breton E-3*	Si. L.	14	.151	−31	− 950	.064	−14	−180	−1130
Breton	Si. L.	15	.113	− 3	− 60	.053	+ 5	+ 50	− 10
Gunn	L.	11	.358	−57	−4060	.052	+18	+190	−3870
Cherhill	Si. L.	11	.219	−45	−1950	.051	+33	+340	−1610
Mackay	Si. L.	3	.072	−35	− 450	—	—	—	—
Mackay	Si. L.	14	.193	− 2	− 60	.071	+ 1	+ 20	− 40
Carrot Creek	Si. L.	5	.284	−59	−3330	.066	− 5	− 70	−3400
Edson	Si. L.	24	.111	−40	− 890	.054	− 3	− 30	− 920
Goodfare	Si. L.	21	.190	−27	−1010	.080	+24	+390	− 620
Love	Si. L.	7	.338	−68	−4610	.059	− 3	− 30	−4640
Average of 13 locations		13	.190	−37	−1579	.060	− 1	− 4	−1583
Average of all samples (19 locations)		—	—	−31	−1257	—	− 4	− 51	−1308

* Complete fertilizer applied annually for last 9 years.

Table 15.—Average losses of nitrogen from cultivated soils of different soil zones

Soil zone	No. locations sampled	Av. no. years cult.	0″–6″			6″–12″			0″–12″
			Nitrogen orig. %	Av. loss		Nitrogen orig. %	Av. loss		Av. loss, lb. per acre
				% of orig.	lb. per acre		% of orig.	Lb. per acre	
Brown	11	16	.235	18	820	.113	3	112	933
Brown	13	—	—	17	779	—	5	110	889
Dark brown	19	22	.326	17	1156	.159	2	41	1197
Dark brown	20	—	—	18	1173	—	1	35	1208
Black	20	26	.487	17	1789	.270	15	811	2600
Black	22	—	—	18	1891	—	15	767	2658
Black-transition	7	24	.714	20	3146	.231	9	353	3662
Gray-transition	4	12	.440	31	2675	.130	+7	+220	2455
Gray	13	13	.190	37	1579	.060	1	4	1583
Gray	19	—	—	31	1257	—	4	51	1308

Table 16.—Significance of losses of nitrogen from cultivated soils of different soil zones (surface and subsurface layers)

Soil zone	Depth	No. cult. fields or locations	Av. no. years cult.	Av. total loss	Min. sig. loss*
				%	%
Brown	0″– 6″	11	18.7	.040	.033
Brown	6″–12″	10	18.4	.012	.015
Dark brown	0″– 6″	19	21.4	.060	.021
Dark brown	6″–12″	19	21.4	.003	.007
Black (including black-transition)	0″– 6″	31	24.8	.097	.035
Black (including black-transition)	6″–12″	30	25.5	.039	.027
Gray (including gray-transition)	0″– 6″	19	14.3	.038	.026
Gray (including gray-transition)	6″–12″	18	14.9	.005	.007
Gray	0″– 6″	13	13.5	.030	.011
Gray	6″–12″	12	14.3	.007	.005

* At 5% level of significance.

When all previously published analyses are included the average loss figures are changed as shown in the tables, but only to a small extent.

As stated previously in connection with the organic carbon results, relatively few samples were obtained from locations within the black-transition and gray-transition soil zones (or sub zones), and consequently the averages obtained from the analyses of these samples are less representative than those of the other soil zones. Moreover, the soils within

the transition zones are frequently quite variable in composition. Most of the black-transition soils sampled were exceptionally rich in nitrogen and organic matter.

A statistical analysis of the data has shown that the average losses of nitrogen from the surface 6 inches of the brown, dark brown, black (including black-transition), gray (including gray-transition) and gray soils, are significant in all cases, and that the losses from the subsurface or 6- to 12-inch depth are significant only in the cases of the black (including black transition) and gray soils (Table 16).

The black and black-transition soils have on the average lost the most nitrogen as well as the most organic matter, whereas the brown and gray soils have lost the least (Table 15). Thus it will be observed that the losses of both nitrogen and organic matter increased with increase in original nitrogen and organic matter content.

Both total losses and percentage of original nitrogen content losses from the subsurface or 6- to 12-inch depth were small on the average as compared to the losses from the upper 6-inch depth (Table 15). This was also true of the organic carbon losses. Both total and percentage of original nitrogen content losses from the 6- to 12-inch depth were greatest in the case of the black soils. This may be due to the fact that the surface organic matter layer is relatively deep in the black soils.

The losses in percentage of original nitrogen content from the surface 6 inches of brown, dark brown, black and black-transition soils were much alike on the average, varying from 17 to 20% (Table 15).

The average losses in percentage of original nitrogen content were 31 and 31% respectively in the cases of the gray and gray-transition soils. These losses were considerably greater than in the cases of the other soil zones.

A grain and fallow system of dry land farming is followed on the Rotation C dark brown soil plots at Lethbridge. This 3-year rotation, consisting of wheat, wheat, and fallow had been followed for 26 years when soil samples were obtained for the analyses shown in Tables 2 and 10.

Rotation U at Lethbridge is a 10-year rotation consisting of 6 years of alfalfa, followed by sugar beets (or another hoed crop), wheat, oats, and barley. This rotation had been followed on irrigated land for 25 years when soil samples were obtained for the analyses shown in Tables 2 and 10. Farm manure had been applied only once every 10 years at the rate of 12 tons per acre.

It will be observed that the losses of organic carbon were small and that the losses of nitrogen were very small in the alfalfa rotation plot soils as compared to the losses from the wheat and fallow rotation plots, and as compared to the average losses at all locations in the dark brown soil zone.

Rotation C, a 3-year grain and fallow rotation consisting of wheat, wheat, and fallow, had been followed on the black soil at Lacombe for 25 years before samples of soil were obtained for the analyses reported in Tables 3 and 11.

Rotation O, at Lacombe, is a 7-year rotation consisting of wheat, oats, fallow, wheat (seeded to alfalfa and rye grass), hay (manured), hay (broken early), and potatoes. This rotation had been followed for 26 years when samples were obtained for the analyses reported in Tables 3 and 11.

The analyses indicate that there was a large loss of organic carbon and some loss of nitrogen from the wheat and fallow rotation plots at Lacombe, whereas there were small gains of organic carbon and nitrogen in the plots under a rotation which includes a legume, grass and manure.

Rotation C at Indian Head is a 3-year, wheat, wheat and fallow rotation (as at Lacombe and Lethbridge). This rotation had been followed on the black soil at Indian Head for 29 years before samples of soil were obtained for the analyses reported in Tables 3 and 11.

Rotation R at Indian Head is a 9-year rotation consisting of wheat, oats, fallow, wheat, oats (seeded down to grass and alfalfa), hay, hay or pasture, pasture (broken), and corn (manured). This rotation had been followed for 29 years when samples were obtained for the analyses reported in Tables 3 and 11.

The analyses indicate that there were large losses of organic carbon and nitrogen from the wheat and fallow rotation plot soil at Indian Head, and losses also, but much smaller losses from this soil under a rotation which includes a mixture of grass and alfalfa, and an application of farm manure.

A grain and fallow system of farming was followed on the gray wooded soil Breton E1 and E3 plots for 14 years before samples were obtained for analysis, as shown in Tables 6 and 14. During this period plot E1 received no fertilizer, whereas plot E3 received 8 annual applications of complete fertilizer at the rate of approximately 100 lb. per acre per year. The analyses indicate that the losses of carbon and nitrogen from these two plots were about equal. The losses of organic carbon were above the average of the gray soils and the losses of nitrogen rather less than average.

A 4-year rotation of crops consisting of wheat, oats, barley (seeded to clover), and clover, was followed on the Breton C1 and C3 plots for 8 years before samples were obtained for analysis as shown in Tables 6 and 14. During this period plot C1 received no fertilizer, whereas plot C3 received 8 annual applications of complete fertilizer at the rate of about 100 pounds per acre per year. The analyses indicate that the losses of organic carbon and nitrogen from these two plots were much alike. The losses of organic carbon were greater than the average loss from the gray soils and the losses of nitrogen about average.

Comparative Rates of Loss of Organic Carbon and Nitrogen from Newer and Older Cultivated Fields

This investigation of soil deterioration includes the determination of losses of several soil constituents from more recently broken fields, as well as from older cultivated fields. Samples of newer and older cultivated fields together with corresponding virgin soils were obtained at 22 locations. The samples were taken close together at each location and represented similar soils. The losses or gains of the individual fields are given in Tables 1 to 6 and 9 to 14. The object was to obtain some estimations of the rates of losses, and, more particularly, to find out if the rate of loss is most rapid during the first few years after the virgin land is broken.

The average annual loss of organic carbon from the older cultivated fields (cultivated on the average for 28.5 years) was approximately half that of the newer cultivated fields (cultivated on the average for 9.2 years), and the average annual loss of nitrogen from the older cultivated fields was less than two-thirds that of the newer fields. (Table 17).

TABLE 17.—COMPARATIVE RATES OF LOSS OF ORGANIC CARBON AND NITROGEN FROM NEWER AND OLDER CULTIVATED FIELDS

——	Depth	No. cult. fields or locations	Av. no. years cult.	Av. ann. loss	Av. total loss	Min. sig. loss*
				%	%	%
			ORGANIC CARBON			
Newer cultivated fields	0″–6″	22	9.2	0.107	0.98	0.51
Older cultivated fields	0″–6″	22	28.5	0.052	1.49	0.49
			NITROGEN			
Newer cultivated fields	0″–6″	22	9.2	.0062	.057	.033
Older cultivated fields	0″–6″	22	28.5	.0038	.108	.041

* At 5% level of significance.

Carbon to Nitrogen Ratios of Virgin and Cultivated Soils

Carbon to nitrogen ratios in different horizons of virgin and cultivated soils are shown in Table 18. These ratios have been calculated from the total organic carbon and total nitrogen data. Separate tabulations have been made for each zone.

TABLE 18.—AVERAGE CARBON TO NITROGEN RATIOS IN DIFFERENT HORIZONS OF VIRGIN AND CULTIVATED SOILS OF VARIOUS SOIL ZONES

Soil zone	Virgin or cultivated av. no. years cult.	Number of locations or samples	Surface horizon C/N	Subsurface horizon C/N	Virgin or cultivated av. no. years cult.	Number of locations or samples	Subsoil horizon C/N
Brown	0	13	12.1	10.7	0	4	11.6
Brown	17	13	11.3	10.0	13	4	10.2
Dark brown	0	20	12.3	10.9	0	3	10.4
Dark brown	22	20	11.6	10.4	16	3	10.4
Black	0	22	12.6	11.5	0	3	12.5
Black	26	22	12.3	11.1	29	3	11.1
Black-transition	0	7	11.8	10.9	0	6	10.5
Black-transition	24	7	11.1	10.3	21	6	9.6
Gray-transition	0	4	10.7	8.2	0	4	8.2
Gray-transition	12	4	10.5	8.2	12	4	8.2
Gray	0	15	17.2	12.1	0	8	11.3
Gray	14	15	15.9	12.1	14	8	10.6

In the brown, dark brown and black soils the average carbon to nitrogen ratio varied only from 10.0 to 12.6. In each of these soil zones the ratio was slightly lower for the subsurface soil (approximate depth 6 to 12 inches) than for the surface soil (approximate depth 0 to 6 inches), and the average ratio in each case was slightly lower in the cultivated soil than in the virgin soil. In the gray soils the average ratio was distinctly lower in the cultivated surface soil than in the virgin and the average ratio was much higher in the surface gray soils than in any other zone soils. The ratio was 15.9 for the cultivated surface soil and 17.2 for the virgin. The average ratio for the gray subsurface soils was 12.1, which is quite similar to that of the other soil zones.

DISCUSSION

All samples of soil were analysed for total organic carbon in order to determine their organic matter content. All samples were analysed for total nitrogen also, because this element is generally required in greater quantity than any other element obtained from the soil by non-legume crops, and nitrogen is frequently a limiting element in crop production. Nitrogen is held in the soil mainly in the form of organic matter, and there is a correlation between the quantities of nitrogen and organic carbon present, as shown in the tables.

The total losses of organic carbon and nitrogen increased with increase in original organic matter content, as might be expected under conditions favourable to decomposition provided by cultivation. Thus the black and black-transition soils have on the average lost most organic matter and nitrogen, whereas the brown and gray soils have lost the least.

The percentage losses, on the other hand, were much alike on the average from the surface 6 inches of brown, dark brown, and black soils, and amounted on the average to about 20% of the original content. The higher average loss of about 30% in the case of the gray soils may be due to the more active or less decomposed condition of the surface forest litter incorporated with the soil when it is first ploughed and cultivated. A more active condition is indicated by the higher carbon to nitrogen ratio of the organic matter present in the upper 6 inches of the gray soils. This ratio was 17.2 for the virgin and 15.9 for the cultivated, whereas the average ratios for the brown, dark brown, and black soils varied only from 10.0 to 12.6.

Both total losses of organic carbon and nitrogen, and percentage of original content losses from the 6- to 12-inch depth were small on the average as compared to the losses from the upper 6-inch depth. This was to be expected because of the relatively low original organic matter content of the 6- to 12-inch depth and because this subsurface layer is less exposed to the effects of cultivation.

Although the average losses of carbon and nitrogen from the upper 6 inches of brown, dark brown, and black soils were only about 20% of the original content (the corresponding losses from the gray soils were about 30%), the losses at different locations were quite variable. In some cases the losses were as great as approximately 50% of the organic carbon and 40% of the nitrogen, whereas in other cases there was no apparent loss.

Therefore in some cases the losses were more serious than the average losses might suggest. However, it must be admitted, as stated elsewhere, that in most cases it was not possible to prove the statistical significance of losses at individual locations.

Soil variability is an important factor in an investigation of this nature. In most cases it was not possible to prove the statistical significance of the losses at a given location, and it was necessary to take samples at a number of locations in order to obtain statistically significant average losses.

The average losses of nitrogen were not as great as those previously determined by Shutt at several locations in the Prairie Provinces (12), but the trends were similar.

Information regarding effects of different crop rotations on the nitrogen content of prairie province soils is being provided by studies in progress at the Division of Chemistry, Science Service, Department of Agriculture, Ottawa. Results obtained in these experiments have been summarized recently by Hopkins and Leahey (6).

Rotations which include legumes and grasses and the addition of farm manure evidently do reduce the losses of organic matter and nitrogen as compared to the losses under grain and fallow rotations. Sometimes gains of organic matter and nitrogen are produced by rotations of the former type. The grain and fallow rotations carried on for 25 to 30 years at Lethbridge, Lacombe and Indian Head, prior to the date of sampling the soil for the analyses shown in this report, all resulted in very large losses of organic carbon and nitrogen. On the other hand the equally old rotations at Lethbridge, Lacombe and Indian Head which included legumes, or legumes and grasses, and barnyard manure, resulted in but small losses of organic carbon and nitrogen at Lethbridge, small gains at Lacombe, and, at Indian Head, much smaller losses than those resulting from the grain and fallow rotation.

At Breton, where the rotation including clover had been carried on for only 8 years prior to the date of sampling (although the field had been under cultivation for 14 years), there was little difference between the composition of the soil under a rotation including clovers and under continuous wheat. The losses of organic carbon from the four cultivated plots analysed, including two which had received complete commercial fertilizer, were greater than the average loss from the gray soils, and the losses of nitrogen were about average. Apparently the period of different treatments was not long enough to produce any marked difference in organic carbon or nitrogen content.

Evidently the losses of organic matter and nitrogen are greatest after the land is first broken, and tend to decrease in later years. The average annual loss of organic carbon from the older cultivated fields (cultivated on the average for 28.5 years) was approximately half that of the newer cultivated fields (cultivated on the average for 9.2 years), and the average annual loss of nitrogen from the older cultivated fields was less than two-thirds that of the newer fields. Thus there is a tendency to reach an equilibrium point, even under a grain and fallow system, at which losses

caused by decomposition, crop absorption and other factors are balanced by gains in organic matter from plant growth, and gains in nitrogen due to non-symbiotic nitrogen fixing bacteria. However, it seems fairly certain that soil fertility would be seriously impaired at this point.

The percentage of organic carbon and nitrogen present at the point of equilibrium would vary no doubt with the different soil zones and with the types of soil within a given zone. In semi-arid western Kansas, Gainey, Sewell and Latshaw (5) found that an equilibrium point is reached at about 0.1 % nitrogen and they suggested that this is higher than the corresponding equilibrium point for soils of humid regions. However, many light textured semi-arid soils in the Prairie Provinces of Canada contain much less than 0.1% nitrogen. The equilibrium point for a heavy textured soil which had produced wheat continuously for over 90 years under humid climatic conditions at Rothamsted in England, was found to be approximately 0.1% (10).

It has been calculated that on the average one-third to one-half, approximately, of the nitrogen lost from the surface 6 inches of cultivated soil in the brown, dark brown, black and gray soil zones was absorbed by the crops grown on the soils. The large proportion of unaccounted for nitrogen may have been lost in various ways. It is quite likely that erosion by wind and water often plays a part in soil deterioration under cultivation even when their effects are not readily observable. Fields that were obviously eroded were not sampled in the course of this investigation.

It is commonly stated that the light coloured gray wooded soils become darker in colour and presumably richer in organic matter under cultivation. However, this darker colour is apparently due rather to the mixing of the surface organic matter with the light coloured leached layer below because decreases in percentage of organic matter and nitrogen greater on the average than those found in the parkland and prairie areas have taken place in these gray wooded soil areas, under the grain and fallow system. One would expect that under the fairly moist climatic conditions of the gray soil zone the nitrogen and organic matter content of soils as deficient in organic matter and nitrogen as these could be at least maintained and probably increased under cultivation, provided that a rotation were followed which included legumes and grasses and the use of barnyard manure, and commercial fertilizers as required.

In this investigation an attempt was made to sample cultivated and adjacent uncultivated soils that were uniform in texture and profile, and free from erosion or drifting, although admittedly it is probably impossible to avoid erosion entirely. Therefore this investigation has little or nothing to do with obvious erosion by wind and water which in some local instances has completely ruined the soil for arable purposes. However, the deterioration measured is probably fairly representative of that of the great majority of prairie province soils which have been farmed by the commonly practised grain and fallow system.

Prior to the initiation of this investigation comparatively few actual determinations of the extent of the losses of nitrogen and organic matter, in relation to general fertility, from prairie province soils, had been made. Reports of losses were commonly based upon observation rather than actual

determinations, and some of these reports have tended to exaggerate and some to minimize the extent of such losses. The losses have been large under the grain and fallow system of farming, amounting on the average, in a period of about 22 years, to approximately one-fifth of the original nitrogen and organic matter content, in the cases of the brown, dark brown, and black soils, and a larger proportionate loss in the case of the gray soils, but not as large as sometimes suggested, and the land in most cases is far from utterly ruined. However, the importance of adopting measures such as the introduction of grasses and legumes into the rotation with grain crops to maintain the fibre and fertility of the soils, where such action has not already been taken, can hardly be over-emphasized, and for this reason there may be some excuse for exaggerating the extent of the losses which have already taken place.

While the grain and fallow system of farming had undoubtedly been responsible for the loss of large quantities of organic matter and fibre from the soils, and while the importance of growing grasses and legumes in rotation with grain crops should be emphasized, it must be admitted that it is very unlikely that the organic matter content of soil consisting originally of prairie grassland could be maintained at its original level under any practical system of cultivation without irrigation. It is generally recognized that the organic matter content of soil under grass tends to be increased, or maintained at a relatively high level, if not overgrazed, as compared to land under cultivation. Some losses of organic matter, fibre, and nitrogen must therefore be expected, but these should not be such as to seriously impair the productivity of the soil.

In any discussion of soil fertility and productivity the importance of weed control should be emphasized. Many serious weeds can be kept under control most economically by seeding the land down to sod forming crops periodically. Such crops help to control various insect pests and plant diseases also.

Serious losses of organic matter and fibre and impairment of physical condition, in the drier regions, and consequent soil deterioration through erosion, may be guarded against by growing grasses in rotation with grain crops (in addition to maintaining a trash cover of stubble and straw on summerfallowed land). In the moister regions both grasses and legumes may be grown in the rotations in order to guard against serious impairment of the soil's physical condition, organic matter content, and fertility. These should be supplemented by the use of barnyard manure where available, and by the use of commercial fertilizers where profitable. It is often impractical to grow a legume in rotation with grain crops in the drier regions of the prairie provinces, but it is commonly practical in such regions to seed the land down to a drought resistant grass for a few years, periodically, and thus restore fibre and organic matter to the soil.

SUMMARY

An extensive invesigation has been made of the effects of cultivation and cropping systems (mainly the commonly practised grain and fallow system) on the chemical composition of prairie province soils, by comparing the composition of virgin and adjacent cultivated soils.

The samples of cultivated soil were obtained from recently broken fields as well as older cultivated fields, the average period of cultivation being just over 22 years.

More than 1000 composite or individual samples of soils from 85 locations in Alberta, Saskatchewan and Manitoba (representing 85 comparisons of virgin and cultivated soil) have been analysed for total organic carbon and nitrogen.

The losses in percentage of original organic carbon content from the surface 6 inches of brown, dark brown, and black soils were much alike on the average, and amounted to about 20% of the original content.

The losses in percentage of original nitrogen content from the surface 6 inches of brown, dark brown, and black soils were also much alike on the average, and amounted to about 18% of the original content.

The losses in percentage of original organic carbon and nitrogen content from the surface 6 inches were greatest in the case of the gray soils, amounting on the average to about 30% of the original content.

Both total losses and percentage of original organic carbon and nitrogen content losses from the subsurface or 6- to 12-inch depth were small on the average as compared to the losses from the upper 6-inch depth.

The average losses of organic matter, in pounds to the depth of 12 inches, from the different soil zones were as follows: brown, 25,566; dark brown, 32,289; black, 62,935; black-transition, 92,115; gray-transition, 39, 632; gray, 28,253.

The average losses of nitrogen, in pounds, to the depth of 12 inches, from the different soil zones were as follows: brown, 889; dark brown, 1208; black, 2658; black-transition, 3662; gray-transition, 2455; gray, 1308.

The black and black-transition soils, originally high in organic matter, have lost most organic carbon and nitrogen, whereas the brown and gray soils, originally relatively low in organic matter, have lost the least.

The losses were quite variable. At some locations the losses were as great as approximately 50% of the original organic carbon and 40% of the nitrogen, whereas in other cases there was no apparent loss.

It was calculated that on the average one-third to one-half, approximately, of the nitrogen lost from the surface 6 inches of cultivated soil in the brown, dark brown, black and gray soil zones, was absorbed by the crops grown on the soils.

The average losses of organic carbon and total nitrogen from the surface 6 inches of the brown, dark brown, black (including black-transition), gray (including gray-transition) and gray soils, were significant in all cases. The losses of organic carbon from the subsurface, or 6- to 12-inch depth, were significant in all cases also, and the losses of total nitrogen were significant in the cases of the black (including black-transition) and gray soils.

Rotations which included legumes and grasses, and the addition of barnyard manure, as carried on for 25 to 30 years at the Lethbridge, Lacombe and Indian Head Dominion Experimental Stations, reduced or

prevented losses of organic matter and nitrogen, as compared to the large losses which resulted from the equally old grain and fallow rotations at the same stations.

The average annual loss of organic carbon from the older cultivated fields (cultivated on the average for 28.5 years) was approximately half that of the newer cultivated fields (cultivated on the average for 9.2 years), and the average annual loss of nitrogen from the older cultivated fields was less than two-thirds that of the newer fields.

The average carbon to nitrogen ratio of the surface 6 inches of brown, dark brown, and black soils varied only from 11.3 to 12.6, whereas the corresponding ratio of the gray soils was 17.2 for the virgin and 15.9 for the cultivated.

Cultivation has tended to produce a narrower carbon to nitrogen ratio in the surface soil.

The carbon to nitrogen ratio of the 6- to 12-inch depth is narrower on the average than that of the surface 6 inches.

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A. C. Caldwell, now Assistant Professor of Soils, University of Minnesota, did the earlier analytical work on this project, and A. M. Dean has been working on special phases of the project recently.

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ERRATUM

In the article entitled, "Pink rot disease of potatoes in British Columbia", by Walter Jones, June 1945 issue of *Scientific Agriculture* (Vol. 25, No. 10, p. 597), the legends under Plates I and II should be interchanged.